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(54) Code division multiple access system providing variable data rate access to a user.

(57) A multi-code code division multiple access system allows a user at a radio transmitter unit to dynamically change its source data bit rate. In response to a user input selecting one of said plurality of source bit rates, an adjustable coding means (220, 281, 204, 224, 244, 210) in the transmitter spreads and transmits the user's digital bit stream received at the selected bit rate to a channel bit rate which at least equals the highest bit rate of said plurality of source bit rates. The plurality of source bit rates includes a basic bit rate R and at least one bit rate which is a multiple M of the basic bit rate R, where M is an integer of at least 1. The user's input selects a particular user source bit rate by identifying a basic bit rate multiple M to a base station that is to receive the transmission.

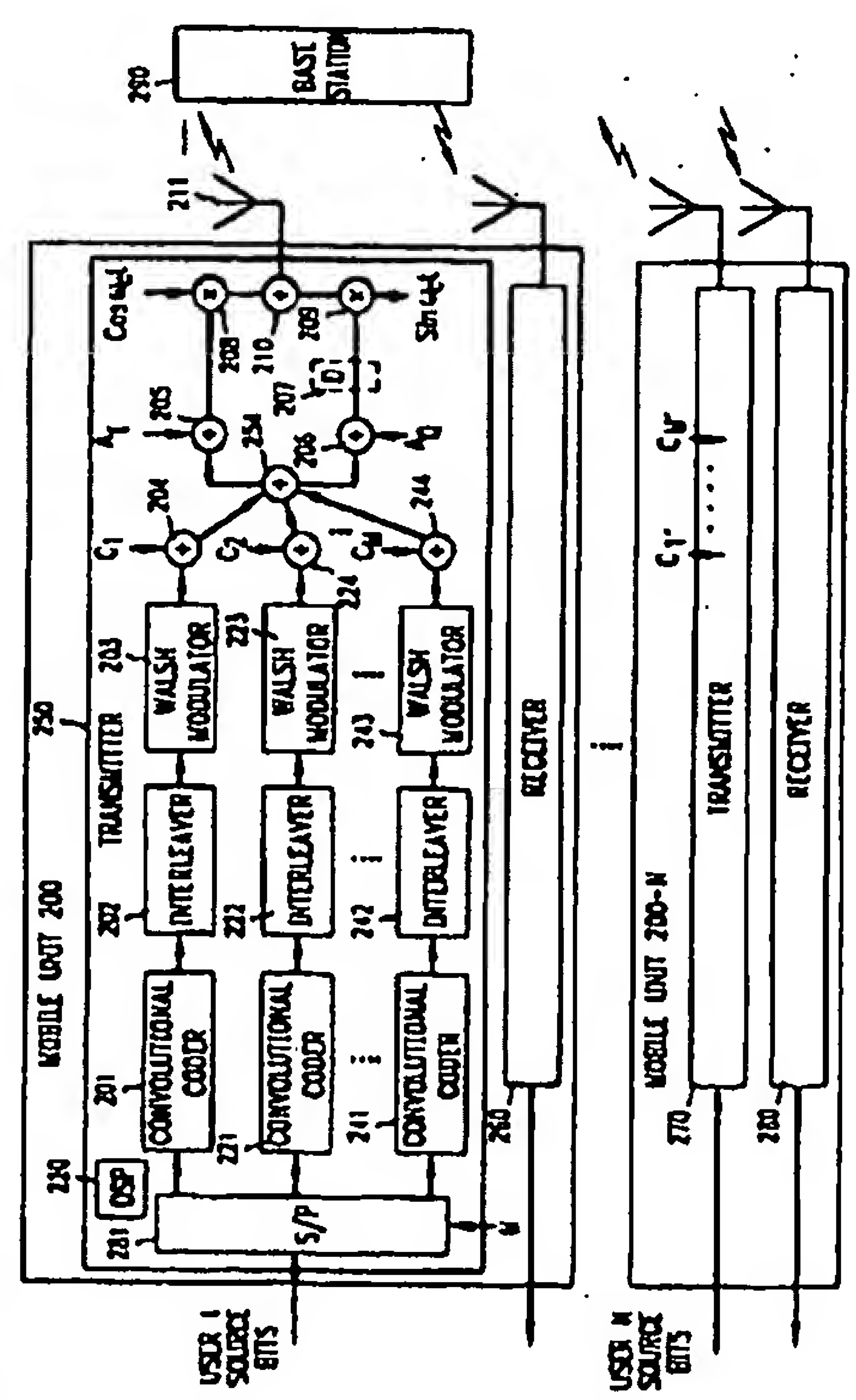

FIG. 2

EP 0 682 423 A2

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Field of the Invention

This invention relates to code division multiple access (CDMA) systems and, more particularly, to a CDMA system for providing a user with variable and dynamic bandwidth capacity access.

Background of the Invention

In future wireless networks, a large variety of services, such as voice/video/data/image, are expected. The most precious resource in most wireless systems is the radio spectrum. To maximize its effective use, packet switched wireless access using code division multiple access (CDMA) has been pursued and offers increased service quality and transmission bandwidth. These CDMA systems provide reduced multiple path distortion and co-channel interference, and avoid the need for frequency planning that is common with frequency division multiple access (FDMA) and time division multiple access (TDMA) systems.

In a CDMA system, a unique binary spreading sequence (a code) is assigned for each call to each user. Multiplied by the assigned code, the user's signal is "spread" onto a channel bandwidth much wider than the user signal bandwidth. The ratio of the system channel bandwidth to the user's bandwidth is commonly called "the spreading gain." All active users share the same system channel bandwidth frequency spectrum at the same time. Given a required signal-to-interference (S/I), the equivalent system capacity is proportional to the spreading gain. The signal of each user is separated from the others at the receiver by using a correlator keyed with the associated code sequence to "de-spread" the desired signal.

In these CDMA systems, there is a continuing need to increase the performance of the system by accommodating users having different source rates.

Summary of the Invention

In accordance with the present invention, a multi-code CDMA system allow a user at a radio transmitter unit to dynamically change its source data rate. In response to a user input selecting one of said plurality of source bit rates, an adjustable coding means spreads and transmits the user's digital information received at the selected bit rate to a channel bit rate which at least equals the highest bit rate of said plurality of source bit rates. According to one feature, the plurality of source bit rates includes a basic bit rate R and at least one bit rate which is a multiple M of the basic bit rate R, where M is an integer of at least 1. The user's input selects a particular user source bit rate by identifying a basic bit rate multiple M to a base station that is to receive the transmission.

Brief Description of the Drawing

FIG. 1 shows a prior art CDMA system;

FIG. 2 shows a block diagram of a first embodiment of a transmitter unit of a multi-code CDMA system in accordance with the present invention;

FIG. 3 shows a block diagram of a second embodiment of a transmitter unit of a multi-code CDMA system;

FIG. 4 shows a block diagram of a third embodiment of a transmitter unit of a multi-code CDMA system;

FIG. 5 shows a flow chart describing how a user can dynamically change the source data bit transmission rate of the transmitter unit; and

FIG. 6 shows an illustrative base station uplink load graph.

Detailed Description

With reference to FIG. 1, we describe a prior art CDMA system. The CDMA system includes a plurality of mobile units (1 - N) which enables a plurality of users (1 - N) to communicate with a base unit 190 at one cell site. Illustratively, a block diagram of mobile unit 1 includes a transmitter unit 150 and a receiver unit 160. The transmitter unit 150 includes a convolutional coder 101 which receives digital information (or data signals) from user 1 at a first data bit rate. The output of convolutional coder 101 is coupled to interleaver 102 and then to a Walsh modulator 103, all of which are well known in the prior art. The output of modulator 103 is outputted into code spreader 104, which spreads the first data bit rate signal into a channel bit rate using a code C_1 which is unique to user 1. The output signal 104a of code spreader 104 is coupled to coders 105 and 106. In coder 105, an in-phase code A_I further encodes the signal 104a. Similarly, coder 106 further encodes the signal 104a using a quadrature-phase code A_Q. The codes A_I and A_Q are common to mobile units 1 - N, but are unique to the cell site base unit 190 which serves mobile units 1 - N. This ensures that mobile units 1 - N can only communicate with base station 190.

The output of coder 105 is used to modulate the carrier signal $Cos\omega_c t$ in modulator 108. The output of coder 106 is used to modulate the carrier signal $Sin\omega_c t$ in modulator 109. In certain applications, an optional delay unit 107 may be utilized to provide better spectral shaping. The output of modulators 108 and 109 are radio frequency signals which are combined in combiner 110 and transmitted via antenna 111 over the air to base unit 190.

The base unit 190 transmits at a different carrier frequency which is received and decoded by mobile units 1 - N. In our illustrative example, receiver 160 of mobile unit 1 includes a demodulator (not shown) to demodulate the carrier frequency to obtain a chan-

nel bit rate signal which is decoded using codes A_I and A_Q and then de-spread using the associated code sequence C_1 to obtain the information data signal to be outputted to user 1.

The base unit 190 operates in a similar manner to receiver 160 of mobile unit 1 to receive, decode and de-spread the user 1 information data signal. Similarly, the other mobile units, illustratively represented by mobile unit N, operate in the same manner as mobile unit 1, except that user N has a unique code CN to distinguish it from user 1. In mobile unit N, the in-phase and quadrature codes A_I and A_Q, respectively, as well as the carrier frequency f_c, are the same as used for mobile unit 1.

When a higher data transmission rate is desired, one prior art arrangement provides the user a multicode mobile unit having a fixed number of multiple transmitters and receiver units, each using a different spreading code. Thus, for example, if a user required twice the bandwidth, the user terminal would include two transmitter units 150 and two receiver units 160, which operate using different codes C_1 and C_2. Such an arrangement is described in WI-LAN Inc. Technical Bulletin No. 3 dated October 1993 and entitled "Multicode Direct Sequence Spread Spectrum." In such an arrangement, however, the user is allocated a predefined fixed bandwidth and all users, when they transmit, would transmit at the same fixed source rate.

With reference to FIG. 2, we describe our dynamic multi-code code division multiple access (MC-CDMA) system. In FIG. 2, the units 205-211 operate in the same manner as the previously described units 105-111 of FIG. 1 and coder units 201-204, 221-224, and 241-244 operate the same as coder units 101-104 of FIG. 1. The units 280, 201-204, and 221-224 may each be implemented using a Digital Signal Processor (DSP) or may be combined in one or more DSPs. Illustratively, the DSP is shown as a separate unit 220 which controls the mobile unit 200. The combiner 254 combines the output of code spreaders 204, 224 and 244. The serial-to-parallel unit 281 converts a user's serial digital information input, which may be up to M_{max} times the basic source rate R (where $M_{max} \bullet R \leq$ channel rate), into M data streams (where M is an integer $\leq M_{max}$) each of which is encoded using one of the coder units (e.g., 201-204). The variable M is selected by a user and/or the base station 290 depending on system status, as will be discussed in a later paragraph. It should be noted that the Walsh modulators 203, 223 and 243 are optional, to improve the required signal-to-interference ratio, and in accordance with an aspect of the invention may be eliminated to improve the bandwidth multiple M_{max}.

In an MC-CDMA system of FIG. 2, if a user 1 requests (and is allowed by the base station 290) M times the basic source rate R, mobile unit 1 converts the user digital stream, User 1, (using serial-to-parallel unit 280) into M basic rate streams. Each of the basic rate streams is encoded using a different code (C_1 - C_M)and they are superimposed together (using combiner 254) and up-converted (using units 208, 209) for radio transmission to the base station 290. The codes C_2 - C_M are derived from C_1 using a subcode concatenation that is described in a later paragraph.

As shown in FIG. 2, such a system does not require modification to the phase encoders 205, 206 or to the RF modulators 208, 209, except for using M times the transmission power (in unit 210) to satisfy the signal-to-interference requirements. All additional processing needed in the MC-CDMA mobile unit 1 is done in the baseband region using digital signal processors (DSPs). As will be described in a later paragraph, each mobile unit 200 through 200 - N is assigned a different primary code C_1 ... C_i by base station 290.

In an alternate embodiment shown in FIG. 3, variable rate convolutional coder, interleaver and Walsh modulator (units 301-303) can be utilized in the MC-CDMA mobile unit 300. In such an arrangement, the bandwidth of units 301-303 is set by the input M. The serial-to-parallel unit 381 is connected to the output of Walsh modulator 303 and converts the user's input digital information stream into M basic data rate serial information streams. The remaining units 304 through 311, 324, 344 and 354 function in the same manner as units 204 through 211, 224, 244 and 254 as previously described in FIG. 2. The receiver unit 360 operates in the same manner as unit 260 of FIG. 2.

An additional embodiment shown in FIG. 4 describes the use of a convolutional coder, interleaver and Walsh modulator (units 401-403) which operate at a constant chip data source rate which is C times the basic data rate R. Because units 401-403 operate at a constant chip rate, they are more simply realized. The user's input digital information stream (at a data rate which is equal to M times the basic data rate R) is inputted to a repeater 450. The repeater 450 multiplies the user digital information stream (at a data rate of M times R) by a factor C/M such that the resulting data bit rate is equal to C times the basic data bit rate R. The random selector circuit 422 connects to the output of Walsh modulator 403 and randomly selects one of the C/M blocks of data. The output of selector circuit 422 is then inputted into serial-to-parallel unit 481 which operates the same as unit 381 of FIG. 3 to generate M data streams. Similarly, the units 404 through 411, 424 and 444 operate in the same manner as units 304 through 311, 324 and 344 of FIG. 3. The receiver 460 operates in the same manner as unit 360 of FIG. 3.

Rate Quantization

On the transmitter side, the actual user source bit rate does not have to be an integer multiple of the basic rate R. Each code (C_1 - C_M) in MC-CDMA carries a basic rate R. If one of the codes is equipped with sub-rate capability (i.e., variable spreading gain to provide 1/2 rate, 1/4 rate, etc.), then there is a much finer quantization in terms of the source bit rate offering to the user. Thus, for example, the user would be able to transmit at 3.25 times the basic rate B.

Synchronization/Acquisition

On the receiver side, the synchronization/acquisition subsystem is very demanding even for regular CDMA systems. The MC-CDMA receiver does not require an M-fold complexity increase in synchronization/acquisition. Since the multipath/delay spread suffered by signals carried on the parallel codes to/from one user would be exactly the same, one well-known searcher circuit for acquisition will suffice for the multiple paths receiver (RAKE) fingers of all the parallel codes.

Subcode Concatenation

To avoid the self-interference that a user employing multiple codes may incur, the present invention provides a subcode concatenation scheme to generate additional codes for the user. The scheme operates as follows: Each user admitted into the system has a primary code assigned to it by the base station. The primary codes (i.e., C_1 , C_1', etc.) of different users are PN codes, i.e., not orthogonal among different users. The multiple codes to/from one user can and should be made orthogonal. If C_1 is the primary code of a user and the user requires a higher rate, the additional codes, C_i, will be derived from C_1 by

$$C_i = C_1 \times D_i,$$

where

$$D_i \perp D_j,\ i \neq j.$$

Obviously, $C_i \perp C_j$, $i \neq j$. This orthogonality is maintained at the receiver since the propagation variations on the parallel codes are the same. In addition to the ability of eliminating self-interference, this scheme helps simplify dynamic access in the sense that explicit multiple code negotiation is not needed. The latter will be made clear in the next section.

Dynamic Access Control

To provide the user dynamic bandwidth access control between bursts, two different approaches may be taken: one uses a demand assignment approach; another uses a probabilistic approach.

Taking a demand assignment approach, users (i.e., mobile units) with data bursts to transmit or users with increased source rates must make requests and wait for assignment by the base station. In conventional orthogonal systems, the assignment (e.g., using well-known RAMA/TRAMA access protocols) gives specific time slots and/or carriers to the user. In our MC-CDMA system, only the *number* of codes needs to be dynamically assigned by the base station. Each user has a unique primary code, i.e., C_1, assigned to it at call setup time. When a user is idle, a very low rate (sub-rate) signaling channel is maintained using its primary code. Not only does this sub-rate channel facilitate synchronization and power control procedures, but also it is used to make multiple code requests prior to a burst transmission. Depending on the user need and the uplink load status, an assignment is made to the requesting user. Upon receiving the *number* assignment from the base station, the user utilizes subcode concatenation to locally generate the corresponding number of codes for its transmission while the receiver at the base station does the same. There is no need for explicit code negotiation. The user, then, transmits at a power level adjusted according to the number of codes it uses as well as the QOS it requires.

The demand assignment access described above uses transmitter-oriented codes. By way of the low-rate maintenance channel, it assures continuous synchronization and power control. This approach requires a dedicated receiver and a dedicated maintenance channel for every user admitted into the system. Alternatively, a common code or a few common codes can be reserved for the burst access request by all users. Such access with receiver-oriented codes will do away with the dedicated resources. However, this approach has the disadvantage of a very significant burst access delay due to access collision as well as the time needed to re-acquire synchronization and power control for every burst.

Taking the probabilistic approach, adaptive access control can be employed. One such technique is described in the co-pending, commonly assigned U.S. patent application entitled "Controlling Power And Access Of Wireless Devices To Base Stations Which Use Coded-Division Multiple Access," Serial No. 08/234757, filed April 28, 1994, and incorporated by reference herein. The base station broadcasts to the mobile units the current uplink load information. Users that have data bursts to transmit will then make probabilistic decisions on whether to transmit. For the decision-making, one useful criterion is that the conditional expected load, given the current load, is optimized. Another criterion is that the conditional probability of the system overload, given the current load, is optimized. As described in the above-cited application, priority for users with on-going bursts over users with new bursts may be desirable and can be incorporated in this control mechanism. Furthermore,

since MC-CDMA users are equipped with a variable rate capability, the decision does not have to be the probability of transmission. Instead, given the current load information, a user can decide to transmit at a lower, yet non-zero, source rate by using a fewer number of codes. The probabilistic approach is attractive in that the user access can be instantaneous, and no central controller is required to dynamically assign spectral resource among users in the cell. The disadvantage of this approach is that the system overload occurs with non-zero probability, which will degrade the overall spectral efficiency.

With reference to the flow chart of FIG. 5, we describe an illustrative sequence of system operations for both the demand assignment and probabilistic approach. In step 501, the user inputs a request for a connection over a common access channel used for communications with the base station. Communications between a mobile unit and the base station may use the previously described RAMA/TRAMA protocol or other access protocols. In step 503, if the connection is not successful, it is re-tried in step 505. If it is successful, then in step 507 the base station assigns a primary code C_1 to the mobile unit over the broadcast channel. The base station prevents collision of transmissions from each of the mobile units by selecting unique primary codes for each mobile unit which is active. Thus, for example, one mobile unit may be assigned a primary code C_1; another is assigned a primary code C_1'.

Returning to our example, following step 507, the user can then communicate to the base station at the basic rate R using the primary code C_1. If the user desires to transmit at other than the basic rate, a request is made as is shown in step 509. In step 509, the user requests M times the basic rate R bandwidth for communications to the base station. Such additional bandwidth may be required by a user that transmits in a burst data mode. The base station, depending on the available bandwidth not presently being utilized by other mobile units, may allow the user to transmit at M' times the basic rate R (where M' is less than or equal to M). In step 513 when the user receives permission to transmit at M' times the basic rate R, the user generates the codes C_2 through $C_{M'}$ using the previously assigned primary code C_1.

At the end of a data burst, when the user returns to an idle mode, subrate signaling is maintained over the C_1 channel. In step 517, it is determined if the user has a new data burst. If the user has a new data burst, control returns to step 509. If there is no new data burst, then in step 519 it is determined whether or not the communications channel should be disconnected, step 521. If the user does not wish to disconnect, control returns to step 515.

For users operating in an isochronous mode (i.e., user is sending continuous data transmissions), the path 522 would be substituted for steps 515 and 517.

If the probabilistic approach is used by a user, then the following sequence of steps is followed. Following step 507, the base station, in step 523, broadcasts the uplink load to all users on the system. The user monitors the uplink load and makes a probabilistic determination of being able to transmit at a multiple M of the basic rate R. One criterion for the decision making could be that the conditional expected load, given a current uplink load, is optimized. Furthermore, given the current uplink load information, a user could then decide to transmit at a lower, yet non-zero, source data rate by using a smaller multiple M. In step 525, the user determines at which multiple M to transmit to the base station.

Optionally, via path 526 following step 507, the base station may, in step 527, transmit to the user the probability of success for transmitting at different multiples M of the basic rate R. Thereafter, the user uses these probabilities to determine at which multiple M to transmit.

To illustrate how the base station handles a user request for additional transmission bandwidth, consider the base station uplink load graph shown in FIG. 6. Assume that a base station has a maximum bandwidth capacity of M_{max} (e.g., 5) times the basic rate R. At time T_1 all of the bandwidth has been assigned; hence, any request from a user for an increased transmission bandwidth would be denied. At time T_2, however, only 40% of the bandwidth capacity is being utilized; at time T_3, 80%; at time T_4, 20%; and at time T_5, 0%.

At time T_2 assume an active user wants to increase its bandwidth by a multiple M = 3 of its basic rate R. The base station could allow that user to utilize a multiple 3; however, the base station would then have no residual bandwidth capacity for newly active users or for increasing the bandwidth of existing active users. In such a situation, the base station would likely allow the requesting user to utilize a multiple M of 2 or 1, thereby leaving a reserve bandwidth for other needs of the system. Assuming the base station allows the user a multiple M = 2, the new base station loading would appear as shown in time T_3 (assuming no other changes).

In a system which enables users to use a probabilistic approach, the base station would broadcast the uplink load shown in FIG. 6 to the users. At time T_1 a user can determine for itself what the probability of successful transmission would be at different transmission data rates. Certainly, a user wanting to increase its transmission data rate would determine that it would have a higher probability of success during time T_2 than at time T_1. Using the received uplink loading information shown in FIG. 6, it is likely that a user would vary its transmission data rate with time to optimally utilize the available bandwidth.

As previously discussed, the base station could

also broadcast to the user the probability of a transmission success at different multiples M (not shown in FIG. 6). The user would then decide at which multiple M to transmit.

The above-described dynamic MC-CDMA assignment schemes provide a unique means for providing a user with variable and dynamic bandwidth capacity access in a wireless network. It provides access to the "peak capacity" of a base station to a single user, without losing traditional CDMA advantages in combating multi-path impairments.

Another feature of the proposed system enables a base station to support a mobile unit population that is much greater than the number of base station receivers which, in turn, is somewhat greater than the number of simultaneous mobile transmissions supported. In such a system, we can, for instance, classify users into two groups in order to reduce the number of receivers required at the base station. For high activity factor or delay-sensitive users, dedicated receivers as well as low-rate maintenance channels could be provided at the base station. Whereas low activity factor or non-delay-sensitive users may, instead, share receiver-oriented codes for burst access requests to get a receiver ready, prior to a transmission burst.

Claims

1. A code division multiple access radio transmitter unit (250), CHARACTERIZED BY

    means for receiving (User 1) a digital bit stream from a user at one of a plurality of source bit rates, wherein said plurality of source bit rates includes a basic bit rate R and at least one other bit rate which is a multiple M of the basic bit rate R, where R and M are positive integers of at least 1, a user input selecting a particular user source bit rate by identifying a basic bit rate multiple M,

    adjustable coding means (220, 281, 204, 224, 244, 210), responsive to said user input, for spreading and transmitting the user digital bit stream received at the selected bit rate to a channel bit rate which at least equals the highest bit rate of said plurality of source bit rates,

    wherein said adjustable coding means includes

    a serial-to-parallel means (281), responsive to a user's input identifying a basic bit rate multiple M, for converting a received user bit stream, which is M times a basic bit rate R, into M basic bit rate streams,

    M encoder means (204, 224, 244) for spreading each of the M basic bit rate streams, using a different spread code C, into M channel bit rate signals, and

    means for combining (210) the M channel bit rate signals into one channel bit rate signal and modulating the channel signal onto a carrier signal for transmission from said transmitter unit.

2. The radio transmitter unit of claim 1 CHARACTERIZED IN THAT the user can dynamically change the selected bit rate during a transmission.

3. A code division multiple access radio transmitter unit CHARACTERIZED BY

    means for receiving a digital bit stream from a user at one of a plurality of source bit rates, wherein said plurality of source bit rates includes a basic bit rate R and at least one other bit rate which is a multiple M of the basic bit rate R, where R and M are positive integers of at least 1, a user input selecting a particular user source bit rate by identifying a basic bit rate multiple M,

    adjustable coding means, responsive to said user input, for spreading and transmitting the user digital bit stream received at the selected bit rate to a channel bit rate which at least equals the highest bit rate of said plurality of source bit rates,

    the radio transmitter unit further comprising

    first means for requesting a communication connection over a common access channel of a communication facility,

    means for receiving a primary code C_1, over a broadcast channel of said facility, said primary code enabling said transmitter unit to transmit at the basic bit rate R,

    second means for requesting over said facility, in response to the user input, a change in transmission rate from the basic bit rate R to a rate which is a multiple M of the basic bit rate R, and wherein

    said adjustable coding means changes its transmission bit rate in response to a control signal received over said facility identifying a multiple M' ($M' \leq M$) times the basic bit rate R at which said radio transmitter unit can transmit.

4. The radio transmitter unit of claim 3 further CHARACTERIZED BY

    means for generating codes C_2 through $C_{M'}$, using said primary code C_1, and wherein

    said adjustable coding means is responsive to the codes C_2 through $C_{M'}$, to enable transmitting the user digital bit stream at a multiple M' times the basic bit rate R.

5. The radio transmitter unit of claim 4 CHARACTERIZED IN THAT one of said codes C_1 through C_M has sub-rate capability.

6. The radio transmitter unit of claim 4 arranged to transmit at a carrier frequency to a base station, and CHARACTERIZED IN THAT

   said codes C_1 through C_M used by said radio transmitter unit are different from the codes used by a second radio transmitter unit which transmits to the base station at said carrier frequency.

7. The radio transmitter unit of claim 1 which communicates with a base station over a facility and FURTHER CHARACTERIZED BY

   means for receiving an uplink control signal over the facility,

   means, responsive to the uplink control signal from the base station, for making a probabilistic determination of the success of the radio transmitter unit transmitting at one or more multiples M of the basic bit rate R, and wherein

   said adjustable coding means is responsive to a determined multiple M for transmitting the user's digital bit stream at M times the basic rate R over the facility.

8. The radio transmitter unit of claim 1 which communicates with a base station over a facility and which is FURTHER CHARACTERIZED BY

   means for receiving a signal from the base station indicating a probability of success for transmissions at different multiples M and wherein

   said adjustable coding means determines which multiple M of the basic bit rate R at which to transmit the user's digital bit stream over the facility.

9. The radio transmitter unit of claim 1 CHARACTERIZED IN THAT

   the user's digital bit stream is received as burst data and wherein

   said adjustable coding means transmits the burst data at a first bit rate and maintains a sub-rate signaling during a silent interval between bursts of data.

10. A method of providing code division multiple access for a radio transmitter unit, CHARACTERIZED BY the steps of

    receiving a digital bit stream from a user at one of a plurality of source bit rates, wherein said plurality of source bit rates includes a basic bit rate R and at least one other bit rate which is a multiple M of the basic bit rate, where R and M are positive integers of at least 1, and

    in response to a user input, selecting a bit rate multiple M,

    converting a received serial user bit stream, which is M times a basic bit rate R, into M parallel basic bit rate streams,

    spreading each of the M basic bit rate streams, using a different spread code C, into M channel bit rate signals,

    combining the M channel bit rate signals into one channel bit rate signal, and

    transmitting the user digital bit stream at the channel bit rate modulated onto a predefined carrier frequency.

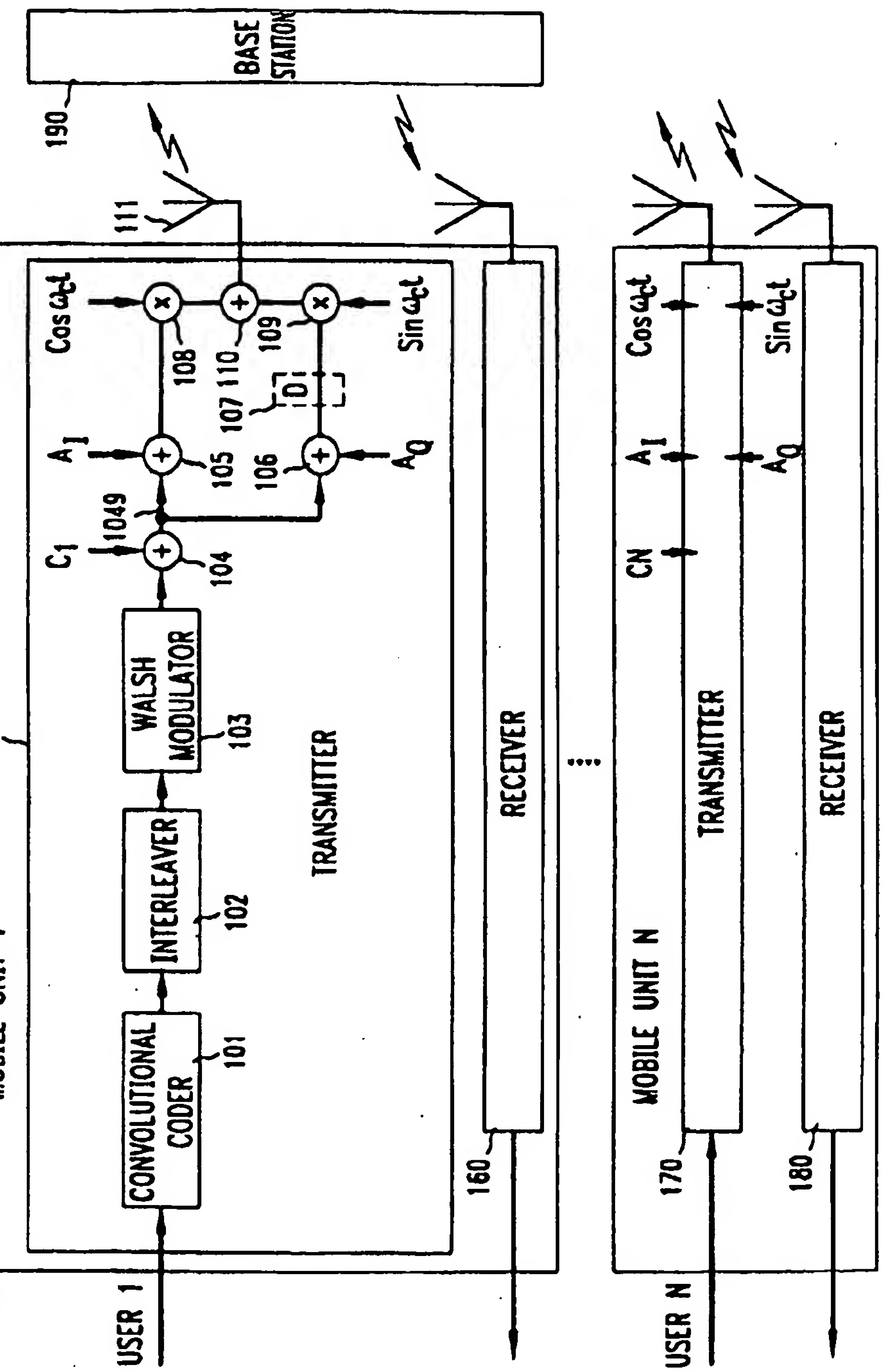
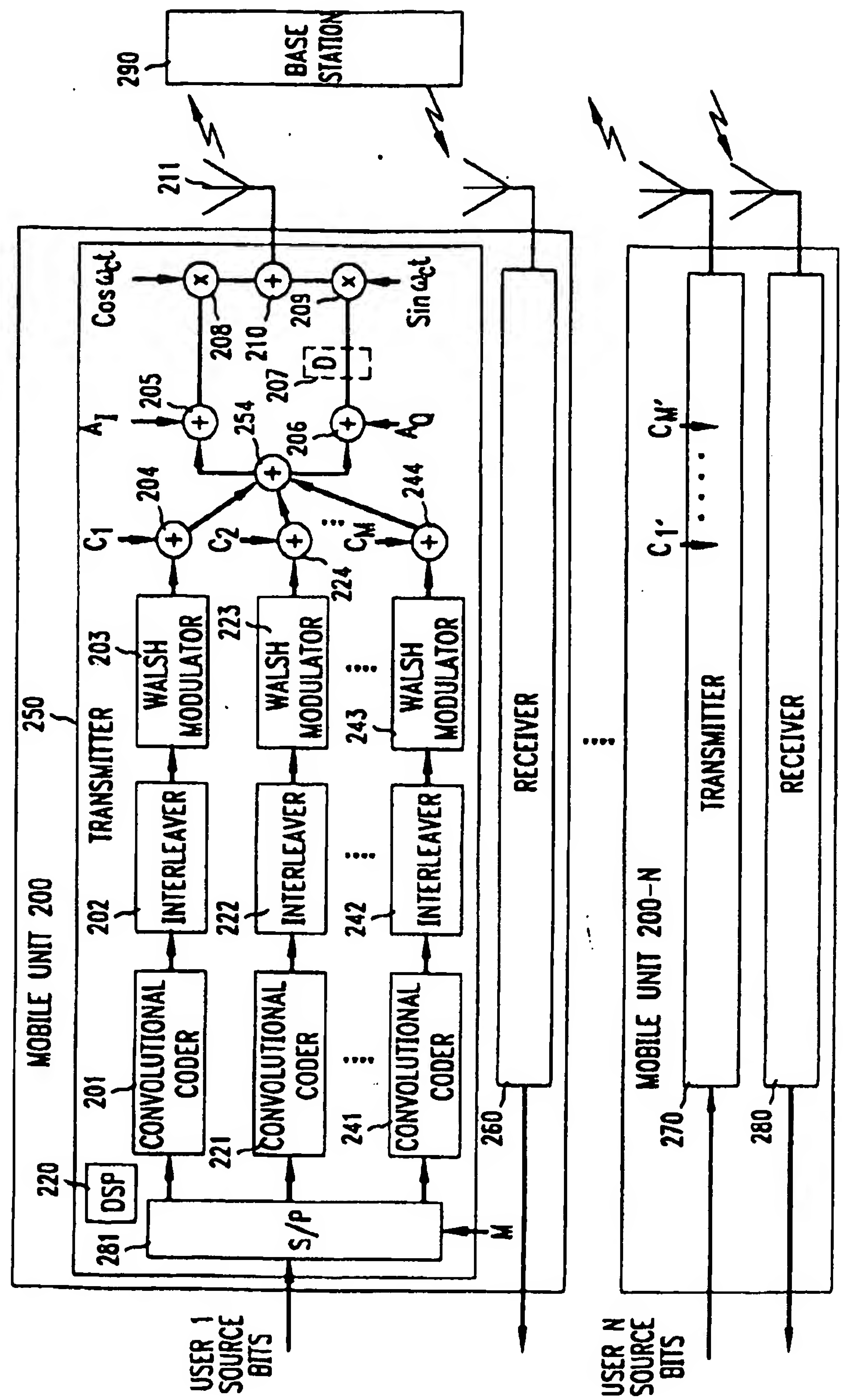


FIG. 1
PRIOR ART

FIG. 2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TRANSMITTER
250
DSP
220
S/P
281
M
CONVOLUTIONAL CODER
201
INTERLEAVER
202
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203
204
CONVOLUTIONAL CODER
221
INTERLEAVER
222
WALSH MODULATOR
223
224
CONVOLUTIONAL CODER
241
INTERLEAVER
242
WALSH MODULATOR
243
244
254
205
206
207
D
208
209
210
211
Cos ωct
Sin ωct
RECEIVER
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USER 1 SOURCE BITS
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TRANSMITTER
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RECEIVER
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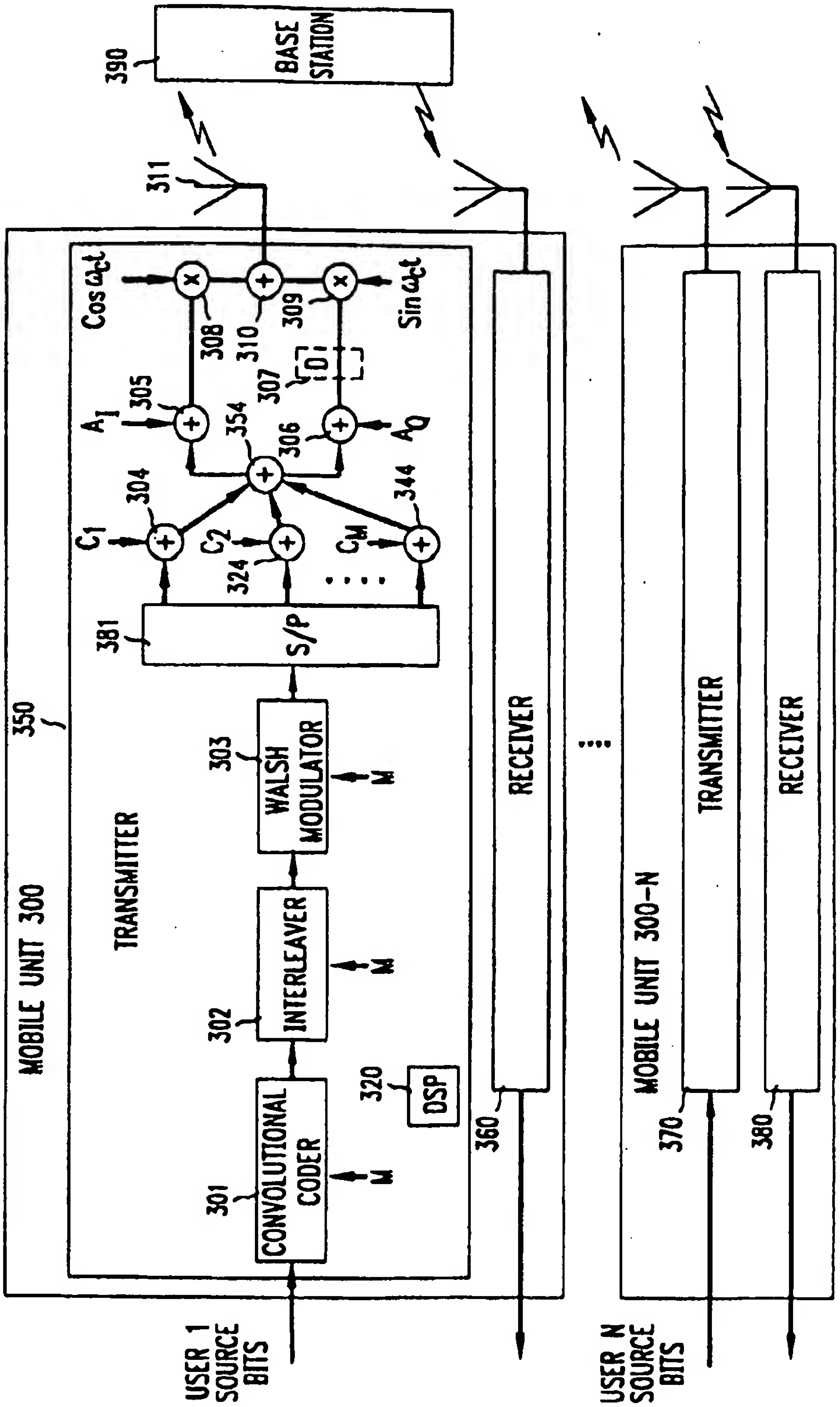
USER N SOURCE BITS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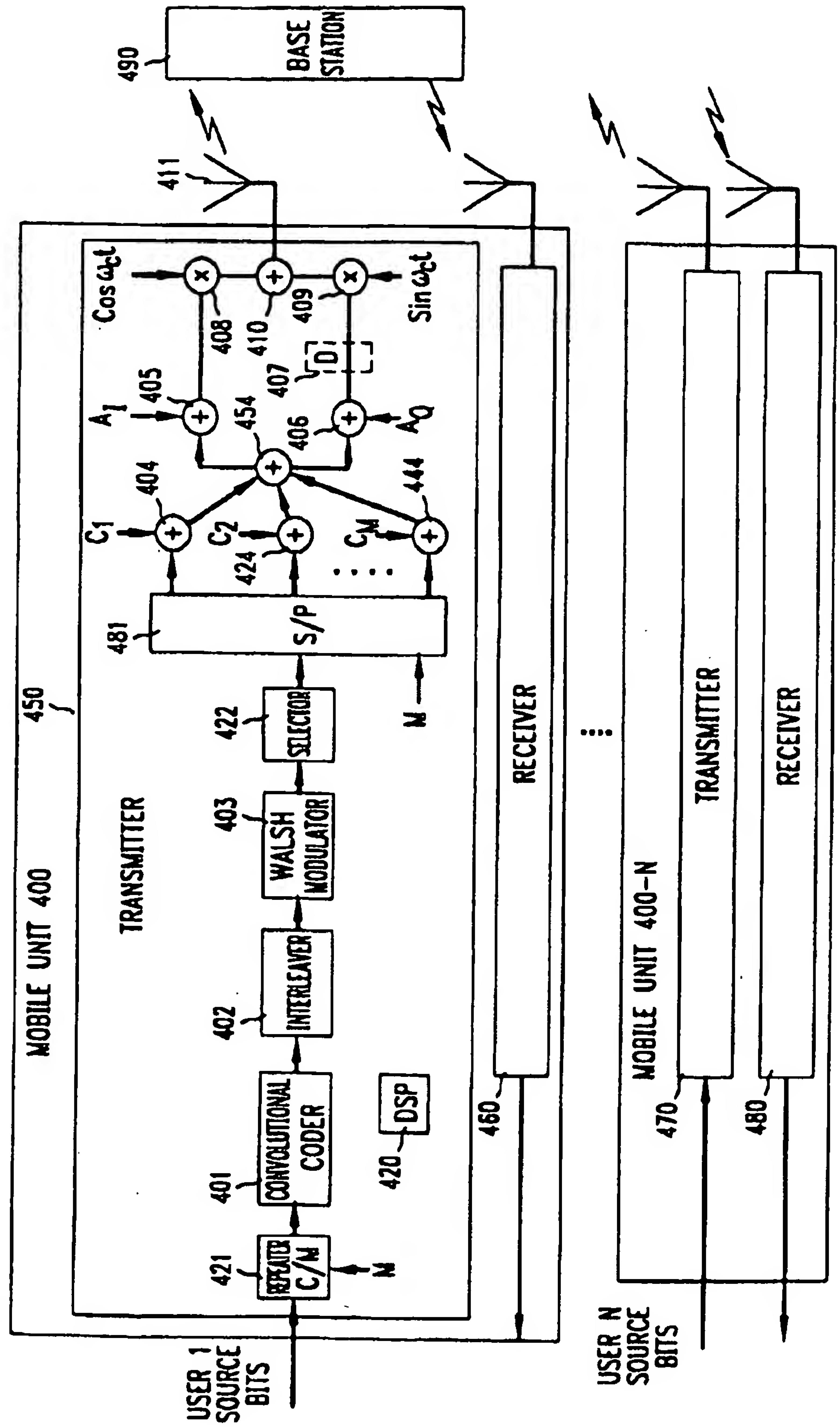
BASE STATION
311
MOBILE UNIT 300
350
TRANSMITTER
CONVOLUTIONAL CODER
301
M
INTERLEAVER
302
M
WALSH MODULATOR
303
M
S/P
381
C_1
C_2
C_M
304
324
344
354
305
306
A_I
A_Q
307
D
308
309
310
Cos $\omega_c t$
Sin $\omega_c t$
DSP
320
RECEIVER
360
MOBILE UNIT 300-N
TRANSMITTER
370
RECEIVER
380
USER 1 SOURCE BITS
USER N SOURCE BITS

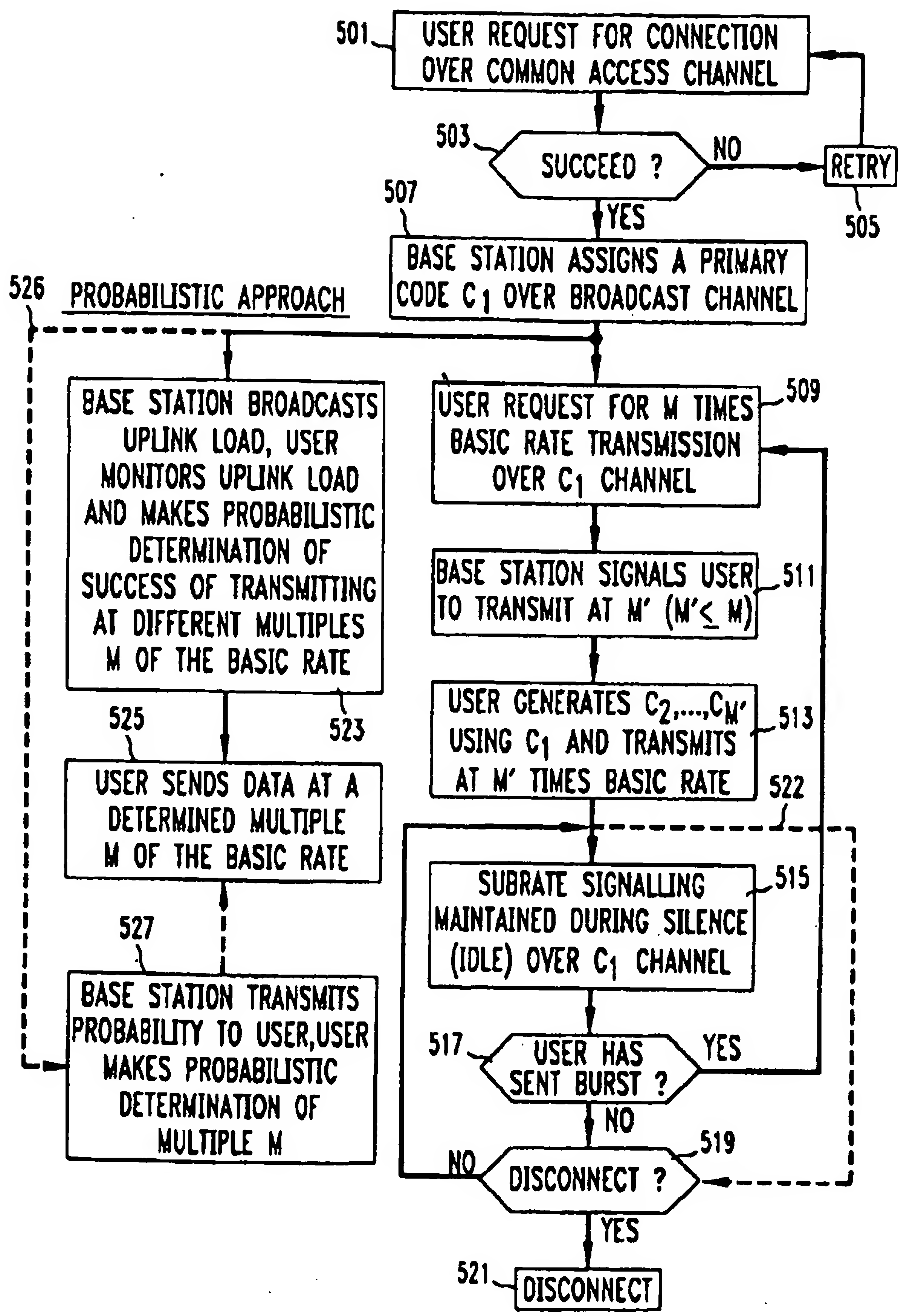
FIG. 3

FIG. 4



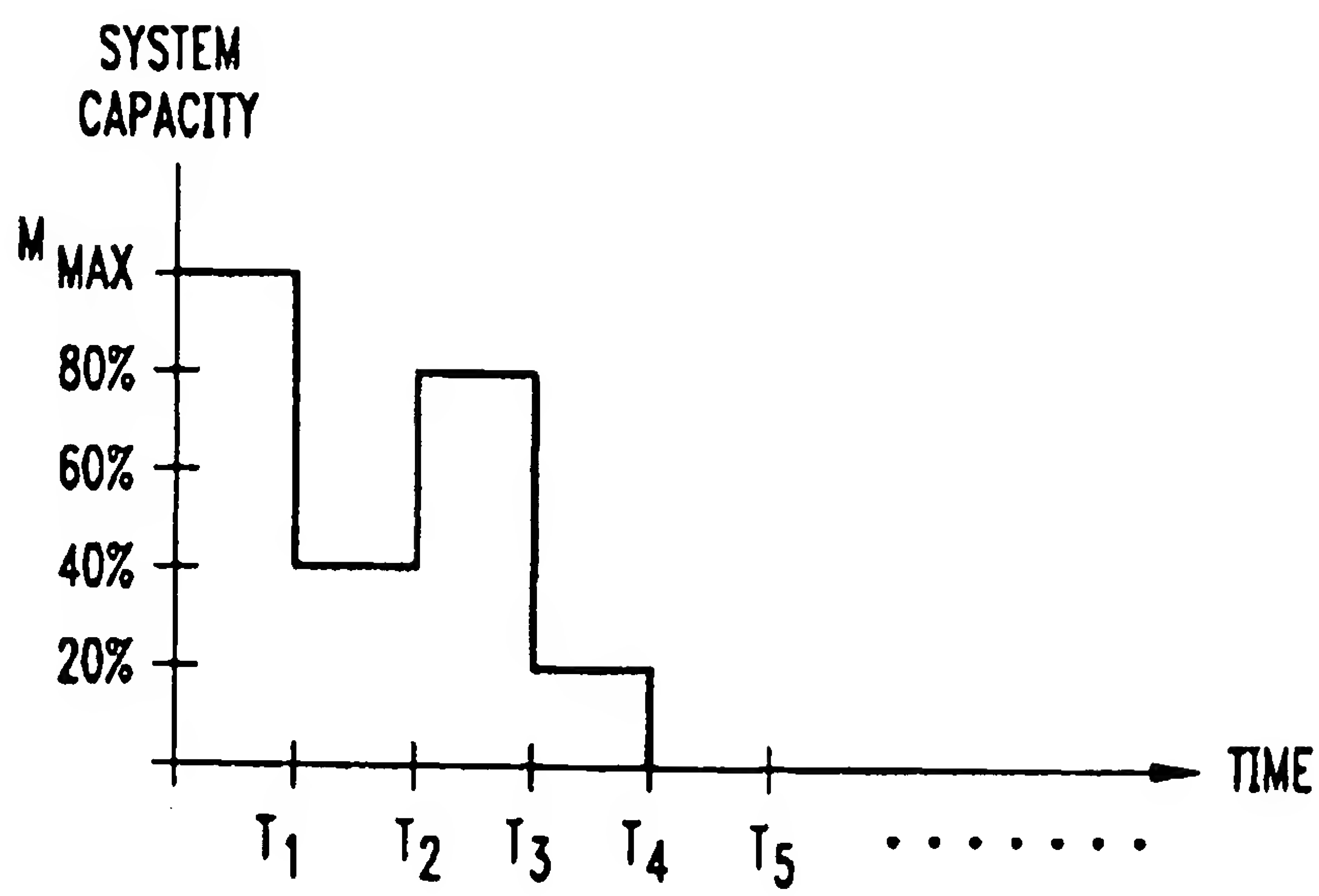
BASE STATION
490
411
MOBILE UNIT 400
450
TRANSMITTER
REPEATER C/M
421
M
CONVOLUTIONAL CODER
401
INTERLEAVER
402
WALSH MODULATOR
403
SELECTOR
422
S/P
481
M
DSP
420
C_1
404
C_2
424
C_M
444
454
A_I
405
A_Q
406
407
D
408
409
410
Cos $\omega_c t$
Sin $\omega_c t$
RECEIVER
460
MOBILE UNIT 400-N
TRANSMITTER
470
RECEIVER
480
USER 1 SOURCE BITS
USER N SOURCE BITS

FIG. 5



501
USER REQUEST FOR CONNECTION OVER COMMON ACCESS CHANNEL
503
SUCCEED ?
NO
RETRY
505
YES
507
BASE STATION ASSIGNS A PRIMARY CODE C1 OVER BROADCAST CHANNEL
526
PROBABILISTIC APPROACH
BASE STATION BROADCASTS UPLINK LOAD, USER MONITORS UPLINK LOAD AND MAKES PROBABILISTIC DETERMINATION OF SUCCESS OF TRANSMITTING AT DIFFERENT MULTIPLES M OF THE BASIC RATE
523
525
USER SENDS DATA AT A DETERMINED MULTIPLE M OF THE BASIC RATE
527
BASE STATION TRANSMITS PROBABILITY TO USER,USER MAKES PROBABILISTIC DETERMINATION OF MULTIPLE M
USER REQUEST FOR M TIMES BASIC RATE TRANSMISSION OVER C1 CHANNEL
509
BASE STATION SIGNALS USER TO TRANSMIT AT M' (M'≤ M)
511
USER GENERATES C2,...,CM' USING C1 AND TRANSMITS AT M' TIMES BASIC RATE
513
522
SUBRATE SIGNALLING MAINTAINED DURING SILENCE (IDLE) OVER C1 CHANNEL
515
517
USER HAS SENT BURST ?
YES
NO
519
NO
DISCONNECT ?
YES
521
DISCONNECT

FIG. 6



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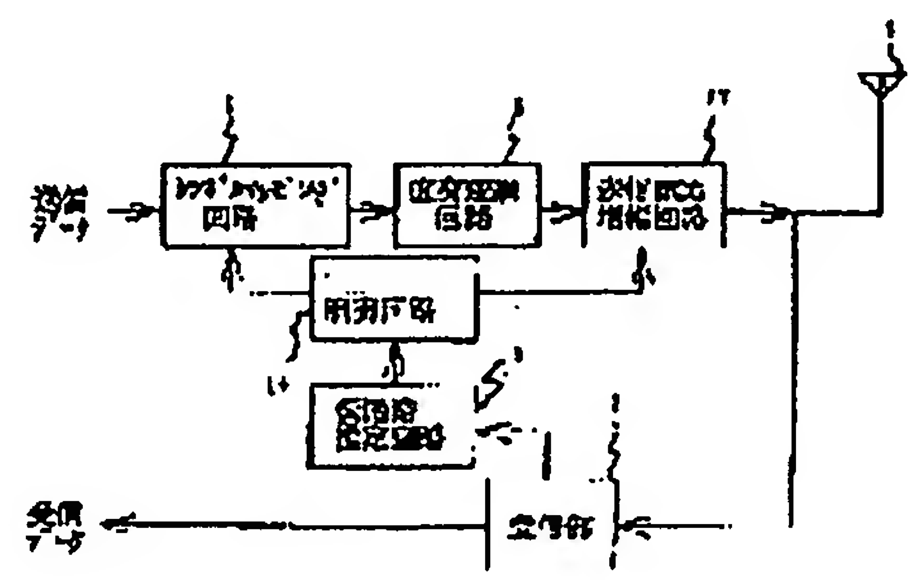
(54) MULTILEVEL ADAPTATIVE MODULATION RADIO DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To improve the power efficiency of a transmission power amplifier circuit by reducing the back-off of the transmission power amplifier circuit when executing transmission under a relatively insufficient transmission line conditions while considering reliability and suppressing the number of bits per symbol.

SOLUTION: A control circuit 14 keeps an error rate in the transmission line conditions at this time to a prescribed value and blow based on an estimation signal by a transmission line estimation circuit 3, selects a modulation system capable of obtaining the maximum information speed and transmits a control signal instructing mapping by this modulation system to a symbol mapping circuit 5. The control signal is transmitted to the transmission power amplifier circuit 17 and instructs the extent of back-off in an amplification operation. When the transmission line conditions is insufficientry, the modulation system is made the system in which multilevel value is small and the zero point of constellation does not cross, then the back-off of the transmission power amplifier circuit 17 is reduced. When the transmission line conditions are satisfactory, the modulation multilevel value is enlarged, and the transmission power amplifier circuit 17 executes an amplification operation in a state large in back-off.



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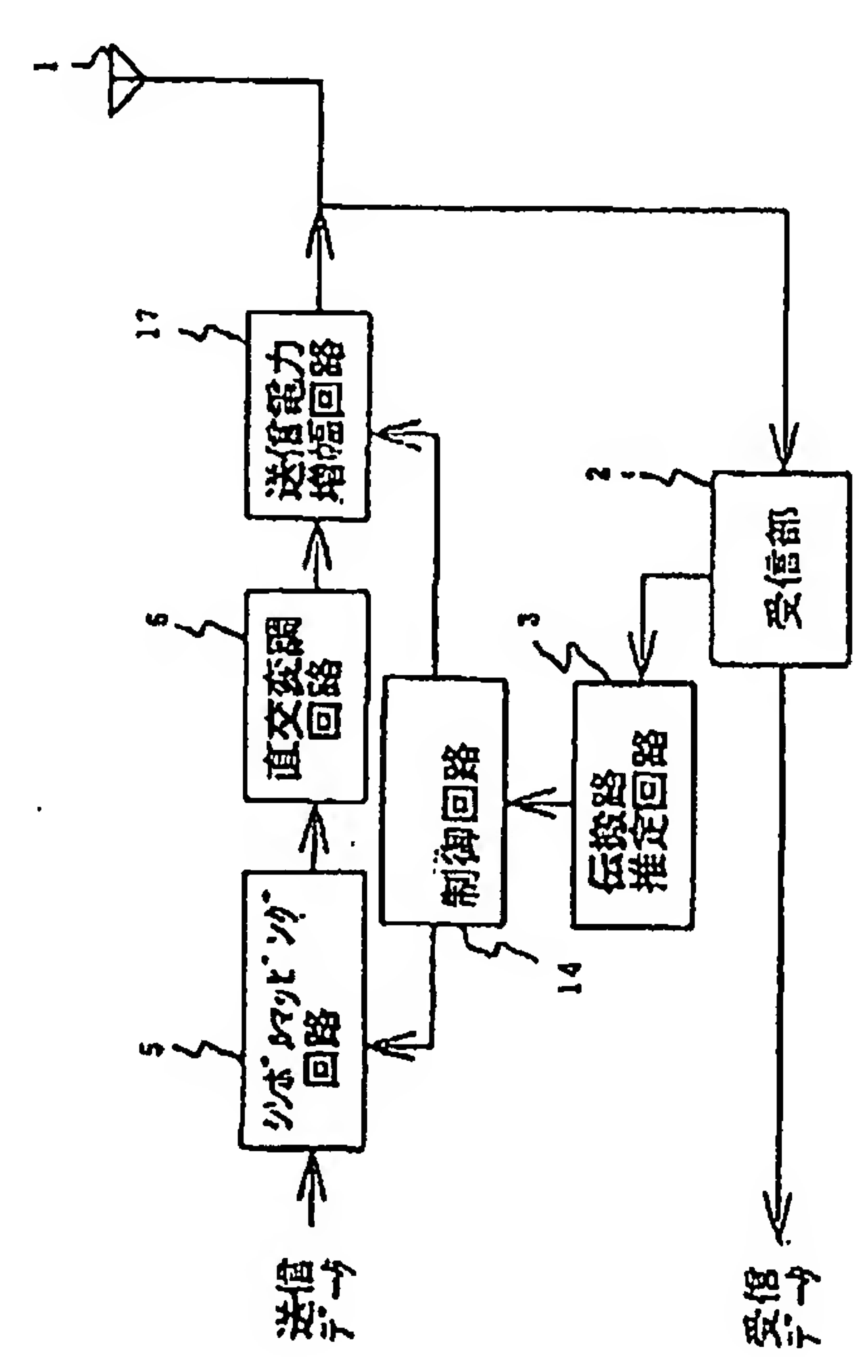
(54)【発明の名称】　多値適応変調無線装置

(57)【要約】

【課題】　送信電力増幅回路の電源効率がよい多値適応変調無線装置を提供する。

【解決手段】　伝搬路状況が良くない場合は、変調多値数が小さく且つコンステレーションの各点を交差しない変調方式を利用するようにした上で、送信電力増幅回路をバックオフの小さい状態で動作させるようにした。



【特許請求の範囲】

【請求項1】 変調に際しては、伝搬路状況に応じて、変調多値数の異なる複数の変調方式のいずれかを選択し、選択した変調方式での変調動作を行なう多値適応変調無線装置において、
後述の制御回路の制御の下に、送信データを指定された変調多値数の変調方式のシンボルにマッピングして、対応する複素ベースバンド信号を送出するシンボルマッピング回路と、
上記シンボルマッピング回路よりの複素ベースバンド信号に基づき、直交変調を行なう直交変調回路と、
後述の制御回路の制御の下に、上記直交変調回路よりの変調波の電力増幅を、指定されたバックオフで行なう送信電力増幅回路と、
受信信号に対して検波および復号の処理を加えて受信データを得て、この受信データを出力する受信回路と、
上記受信回路から受信ベースバンド信号若しくは受信レベル情報の一方、又はそれら両方を取込み、この取込んだ信号等に基づき、伝搬路状況を推定して、推定結果である推定信号を送出する伝搬路推定回路と、
上記伝搬路推定回路よりの推定信号が、伝搬路状況は比較的悪いと推定するものであるときには、上記シンボルマッピング回路に対して、変調多値数が4以下で且つコンステレーションの零点を交差しないように構成した変調方式を指定すると共に、上記送信電力増幅回路に対して、小さいバックオフでの動作を指定し、他方、上記推定信号が、伝搬路状況は比較的良いと推定するものであるときには、上記シンボルマッピング回路に対して、変調多値数が4を越える変調方式を指定すると共に、上記送信電力増幅回路に対して、線形領域のみを利用する大きなバックオフでの動作を指定する制御回路とを備えることを特徴とする多値適応変調無線装置。

【請求項2】 上記制御回路は、変調多値数が4以下の変調方式としては、π／2シフトＢＰＳＫ又はπ／4シフトＱＰＳＫを選択的に指定し、変調多値数が4を越える変調方式としては、π／4シフトＱＰＳＫとＡＳＫとを組合わせた方式又はスター16ＱＡＭを選択的に指定する回路であることを特徴とする請求項1記載の多値適応変調無線装置。

【請求項3】 上記制御回路は、変調多値数が4を越える変調方式の1つとしてπ／4シフトＱＰＳＫとＡＳＫとトレリス符号化変調とを組合わせた変調方式をも指定する回路であることを特徴とする請求項2記載の多値適応変調無線装置。

【請求項4】 上記制御回路は、変調多値数が4以下の変調方式としては、π／2シフトＢＰＳＫ又はＯＱＰＳＫを選択的に指定し、変調多値数が4を越える変調方式としては、ＯＱＰＳＫとＡＳＫを組合わせた方式又は16ＱＡＭを選択的に指定する回路であることを特徴とする請求項1記載の多値適応変調無線装置。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本願発明は、ＴＤＤ（Time Division Duplex）通信方式のディジタル無線通信において、受信した信号から伝搬路状況（すなわち回線の品質）を推定し、この推定結果に応じて変調方式を自動的に切替えて変調動作を行ない、その上で送信等を行なう多値適応変調無線装置に関する。

【0002】

【従来の技術】受信信号と送信信号とを同一の周波数で交互に送受信するＴＤＤ通信で用いる従来の多値適応変調無線装置としては、例えば、スクウェア型多値ＱＡＭの変調多値数およびシンボルレート（すなわち伝送レート）を伝搬路状況に応じて、自動的に切替える図4に示すようなものが公表されている（電子情報通信学会技術報告ＲＣＳ９４－６４）。なお、ＴＤＤ通信で用いられるこの種の多値適応変調無線装置は、以下の点に着目するものである。すなわち連続する受信信号と送信信号とは、可逆性原理により、同じフェージング変動をしている伝搬路を通るとみなせるので、受信信号から測定した伝搬路のＣ／Ｎｏ（搬送波電力対雑音電力密度比）や遅延スプレッドを用いて、次の送信タイミングにおける伝搬路状況を推定できる点に着目するものである。

【0003】図4において、受信部2は、送受信アンテナ1で受信した受信信号に対し直交検波および復号等を行ない受信データを得て、この受信データを送出する回路部である。伝搬路推定回路3は、受信部2から受信ベースバンド信号やＲＳＳＩ（Received Signal Strength Indicator）等の受信レベル情報を取込み、これらを用いて今回の受信タイミングにおけるＣ／Ｎｏや遅延スプレッド等を検出し、検出結果に基づいて次の送信タイミングにおける伝搬路状況を推定し、推定結果である推定信号を送出する回路である。

【0004】変調レベル制御回路4は、上記伝搬路推定回路3からの推定信号を入力し、この信号に基づいて、上記伝搬路状況下で（すなわち推定した伝搬路状況下で）、誤り率を所定値以下に保ちつつ、最大の情報速度を得られる変調方式およびシンボルレートの組合わせを選択して、この組合わせでの変調を指示する制御信号をシンボルマッピング回路5に送出する回路部である。

【0005】シンボルマッピング回路5は、与えられた送信データを上記変調レベル制御回路4よりの制御信号で指示された変調方式のシンボルにマッピングし、更に上記制御信号で指示されたシンボルレート（伝送レート）での複素ベースバンド信号を得て、この信号を直交変調回路6に送出する回路部である。直交変調回路6は、搬送波を上記シンボルマッピング回路5からの複素ベースバンド信号により変調し、変調波を送信電力増幅回路7に送出する回路部である。送信電力増幅回路7は、線形すなわちＡ級の電力増幅器となっており、上記

直交変調回路6からの変調波を入力して、この変調波の電力を増幅して出力する回路部である。この送信電力増幅回路7で電力増幅された上記変調波は、送受信アンテナ1より空間に輻射されることになる。

【0006】ところで、上記変調レベル制御回路4がシンボルマッピング回路5に指示する各変調方式においては、図5に示すように、変調多値数が大きくなる程、1シンボル当りの情報量は増えるが、信頼度（伝搬路状況が比較的劣悪でも誤り率を一定値以下に保てる度合）は低下し、逆に変調多値数が小さくなる程、1シンボル当りの情報量は減少するが、信頼度は向上する。すなわち上記変調レベル制御回路4は、適応変調を実行するため、伝搬路状況が比較的劣悪であると判断されたときは、変調多値数が小さく信頼度が高い変調方式（伝搬状況が最悪のときは、ダミーデータ伝送）を指示し、他方、伝搬路状況が比較的良好であると判断されたときは、変調多値数が大きく信頼度が比較的低い変調方式を指示する。このようにして伝搬状況に応じた適応変調を行うことにより、ビットエラーレート等により見極められる情報伝送の質が向上することになる。

【0007】

【発明が解決しようとする課題】ところで上記のような従来の多値適応変調無線装置においては、上記送信電力増幅回路7として、電源効率の点で劣るバックオフの大きな線形電力増幅器（すなわちA級電力増幅器）を用いている。バックオフの大きな線形電力増幅器を用いる理由は、バックオフの小さい飽和電力増幅器（たとえば、AB級電力増幅器）を用いた場合には、変調波の包絡線変動が大きいときに、スペクトラム歪みが発生し、この歪みは多値QAMのような線形変調では送信信号の振幅や位相の歪みを引起し、このような送信信号を受信した受信側では、送信信号からの送信情報の抽出は、極めて困難になるからである。図6は、上記理由を、一層、具体的に説明するためのものであり、同図の（a）は、送信電力増幅器としてバックオフが大きいA級電力増幅器を用いた場合の送信スペクトラムを示し、また同図の（b）は、送信電力増幅増幅器としてバックオフが小さい例えばAB級電力増幅器を用いた場合の送信スペクトラムを示している。上記（a）と（b）の送信スペクトラムを比較すると（b）の方は（バックオフが小さい方）は、（a）の方（バックオフが大きい方）に比べてサイドローブが盛上がっており、歪みが発生していることが分かる。この歪みの有無が、同図の（c）および（d）に示すコンステレーション歪みの有無すなわち送信信号の振幅や位相の歪みの有無につながるのである。そして、上記（d）に示すようなコンステレーション歪みを持つ送信信号すなわち振幅や位相が歪んでいる送信信号から送信情報を抽出することは極めて困難になるのである。

【0008】以上のような理由により、従来、上記送信電力増幅回路7としてはバックオフの大きな線形電力増幅を用いてきたが、これは、上述のように電源効率が悪く、電力消費といった面で問題がある。

【0009】本願発明は、上述のような事情に鑑みて、なされたものであり、送信電力増幅回路を幾分でも電源効率のよいものにすることができる多値適応変調無線装置の提供を目的とする。

【0010】

【課題を解決するための手段】請求項1の発明では、変調に際しては伝搬路状況に応じて変調多値数の異なる複数の変調方式のいずれかを選択し、選択した変調方式での変調動作を行なう多値適応変調無線装置を以下のように構成した。

【0011】後述の制御回路の制御の下に、送信データを指定された変調多値数の変調方式のシンボルにマッピングして、対応する複素ベースバンド信号を送出するシンボルマッピング回路と、上記シンボルマッピング回路よりの複素ベースバンド信号に基づき、直交変調を行なう直交変調回路と、後述の制御回路の制御の下に、上記直交変調回路よりの変調波の電力増幅を、指定されたバックオフで行なう送信電力増幅回路と、受信信号に対して検波および復号の処理を加えて受信データを得て、この受信データを出力する受信回路と、上記受信回路から受信ベースバンド信号若しくは受信レベル情報の一方、又はそれら両方を取込み、この取込んだ信号等に基づき、伝搬路状況を推定して、推定結果である推定信号を送出する伝搬路推定回路と、上記伝搬路推定回路よりの推定信号が、伝搬路状況は比較的悪いと推定するものであるときには、上記シンボルマッピング回路に対して、変調多値数が4以下でコンステレーション（ディジタル直交変調の信号配置図）の零点を交差しないように構成した変調方式を指定すると共に、上記送信電力増幅回路に対して、小さいバックオフでの動作を指定し、他方、上記推定信号が、伝搬路状況は比較的良いと推定するものであるときには、上記シンボルマッピング回路に対して、変調多値数が4を越える変調方式を指定すると共に、上記送信電力増幅回路に対して、線形領域のみを利用する大きなバックオフでの動作を指定する制御回路とを備える構成とした。

【0012】請求項2の発明では、請求項1の発明に係る多値適応変調無線装置の上記制御回路を、変調多値数が4以下の変調方式としては、π／2シフトBPSK（π／2シフト2値位相変調）又はπ／4シフトQPSK（π／4シフト直交位相変調）を選択的に指定し、変調多値数が4を越える変調方式としては、π／4シフトQPSKとASK（振幅変調）とを組合わせた方式又はスター16QAM（スター16値直交振幅変調）を選択的に指定する回路とした。

【0013】請求項3の発明では、請求項2の発明に係る多値適応変調無線装置の上記制御回路を、変調多値数

が４を越える変調方式の１つとしてπ／４シフトＱＰＳＫとＡＳＫとトレリス符号化変調とを組合わせた変調方式をも指定する回路とした。

【００１４】請求項４の発明では、請求項１の発明に係る多値適応変調無線装置の上記制御回路を、多値数が４以下の変調方式としては、π／２シフトＢＰＳＫ又はＯＱＰＳＫ（オフセット直交位相変調）を選択的に指定し、変調多値数が４を越える変調方式としては、ＯＱＰＳＫとＡＳＫを組合わせた方式又は１６ＱＡＭ（１６値直交振幅変調）を選択的に指定する回路とした。

【００１５】

【発明の実施の形態】以下、本願発明の実施の形態により、本願発明を具体的に説明する。図１は、本願発明の実施の形態に係る多値適応変調無線装置の構成を示すものである。同図において、従来例を示す前記図４における回路部と同一符号が付されている回路部は、図４における回路部と同一構成および機能を備えるものとなっている。すなわち、図４における変調レベル制御回路４および送信電力増幅回路７は、図１においては、それぞれ制御回路１４および送信電力増幅回路１７に変更されているが、他の回路部については、概ね変更はない。

【００１６】図１において、制御回路１４は、伝搬路推定回路３からの前記推定信号を入力し、この信号に基づいて、その時点の伝搬路状況で（すなわち推定した伝搬路状況下で）誤り率を所定値以下に保ちつつ、最大の情報速度が得られる変調方式を選択して、この変調方式でのマッピングを指示する制御信号をシンボルマッピング回路５に送出すると共に、送信電力増幅回路１７にも制御信号を送ってこの送信電力増幅回路１７の増幅動作におけるバックオフの大きさを指示する回路になっている。また図１における送信電力増幅回路１７は、直交変調回路６からの変調波を入力して、これを制御回路１４によって指示された大きさのバックオフでの電力増幅を行なって送出する回路部となっている。

【００１７】以上のように構成された本実施の形態においては、伝搬路推定回路３は伝搬路状況を悪い方から順にＡ、Ｂ、Ｃ、Ｄ、Ｅの５段階に分けて評価する。例えば伝搬路状況が最も悪く評価がＡであるときは、このＡを示す推定信号を伝搬路推定回路３から与えられた制御回路１４は、シンボルマッピング回路５に対し変調方式として図２の（ａ）に示すπ／２シフトＢＰＳＫを指示すると共に、送信電力増幅回路１７に対しては、バックオフを小さくした状態での増幅動作を指示する。また伝搬路状況が比較的悪く、評価がＢのときは、このＢを示す推定信号を伝搬路推定回路３から与えられた制御回路１４はシンボルマッピング回路５に対し、変調方式として、図２の（ｂ）に示すπ／４シフトＱＰＳＫを指示すると共に、送信電力増幅回路１７に対してはバックオフを小さくした状態での増幅動作を指示する。

【００１８】また、伝搬路状況が比較的良好で評価がＣのときは、このＣを示す推定信号を伝搬路推定回路３から与えられた制御回路１４はシンボルマッピング回路５に対し、変調方式として、図２の（ｃ）に示すπ／４シフトＱＰＳＫとＡＳＫとＴＣＭ（トレリス符号化変調）を組合わせたものを指示すると共に、送信電力増幅回路１７に対しては、バックオフを大きくした状態での増幅動作を指示する。評価がＤのときは、制御回路１４はシンボルマッピング回路５に対し、変調方式として、図２の（ｄ）に示すπ／４シフトＱＰＳＫとＡＳＫとを組合わせたものを指示すると共に、送信電力増幅回路１７に対しては、バックオフを大きくした状態での増幅動作を指示する。そして、伝搬状況が極めて良好で、評価がＥのときは、制御回路１４はシンボルマッピング回路５に対して、変調方式として、図２の（ｅ）に示すスター型１６ＱＡＭを指示すると共に、送信電力増幅回路１７に対してはバックオフを大きくした状態での増幅動作を指示する。

【００１９】以上のように、この実施の形態においては、評価がＡまたはＢの場合のように伝搬路状況が良くない場合は、変調方式を多値数が小さく且つコンステレーションの審点を交差しないものとし、その上で送信電力増幅回路１７のバックオフを小さくしてこの送信電力増幅回路１７にＡＢ級増幅動作をさせて高電源効率を実現している。この場合、送信電力増幅回路１７のバックオフを小さくできるのは、上記変調方式で変調した変調波の振幅には変調情報が含まれないためである。また、評価がＣ、ＤまたはＥの場合のように伝搬路状況が良いときは、従来の多値適応変調無線装置と同様で、この良好の伝搬路状況を活用するために変調多値数の大きな変調方式を用い、送信電力増幅回路１７にはバックオフの大きな状態での増幅動作（例えばＡ級増幅動作）をさせている。これは、変調多値数の大きな変調方式で変調した変調波では、振幅にも変調情報が含まれるので、線形領域での増幅動作の確保が必要だからである（すなわち従来例において送信電力増幅回路７にＡ級増幅動作をさせていた理由と同様の理由である）。

【００２０】以上のように、この実施の形態によれば、伝搬路状況が比較的良くなく、信頼度を重視し、１シンボル当りのビット数を押さえて伝送を行なっているときには、送信電力増幅回路１７のバックオフを小さくして、この送信電力増幅回路１７の電源効率を高いものとすることができる。

【００２１】なお、本願発明は、上記実施の形態に限定されるものでなく、本願発明の範囲で種々応用変形が可能である。例えば、上記実施の形態では伝搬路状況をＡ、Ｂ、Ｃ、Ｄ、Ｅの５段階で評価し、この評価に応じて、図２に示す各変調方式を切替えて利用するものであったが、伝搬路状況を悪い方から順に、Ａ、Ｂ、Ｃ、Ｄの４段階で評価し、この評価に応じて、図３に示す各変調方式を切替えて利用するようにしてもよい。すなわち

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評価がAのときはπ／2シフトBPSK、評価がBのときはOQPSK、評価がCのときはOQPSKとASKを組合せたもの、評価が最良でDのときは16QAMといった具合に切替えて利用するようにしてもよい。なお、このような変調方式の切替えにおいても、伝搬路状況が悪いときは、コンステレーションの符点を交差しないように構成した変調多値数の小さい変調方式を利用しているので、送信電力増幅回路17をバックオフの小さい状態で利用でき、この送信電力増幅回路17の電源効率を高いものとすることができる。

【0022】

【発明の効果】以上詳述したように、本願発明によれば、送信電力増幅回路の電源効率を良くすることができる多値適応変調無線装置の提供を可能とする。

【図面の簡単な説明】

【図1】本願発明の実施の一形態の回路構成を示す図である。

【図2】上記実施の形態において切替えて利用される変調方式を示す図である。

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【図3】応用変形例において切替えて利用される変調方式を示す図である。

【図4】従来例の回路構成を示す図である。

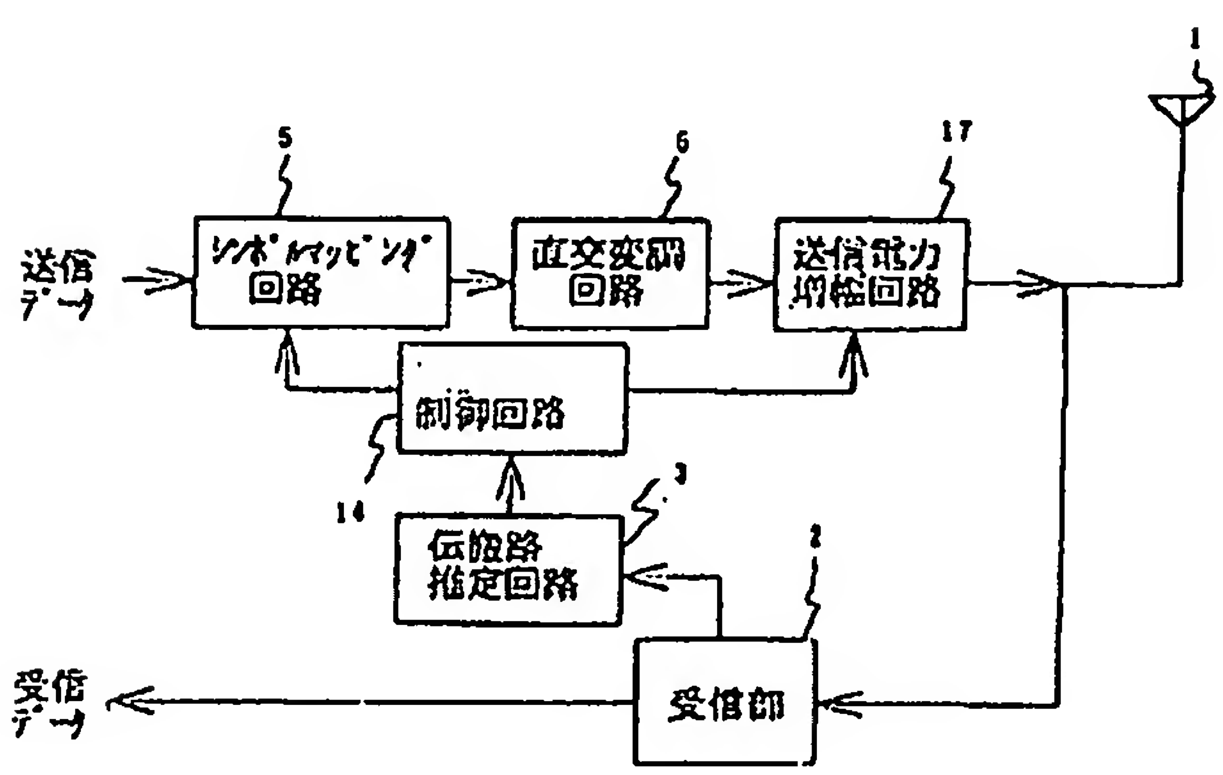
【図5】従来例において切替えて利用される変調方式を示す図である。

【図6】従来例においてA級電力増幅器が用いられる理由を説明するための図である。

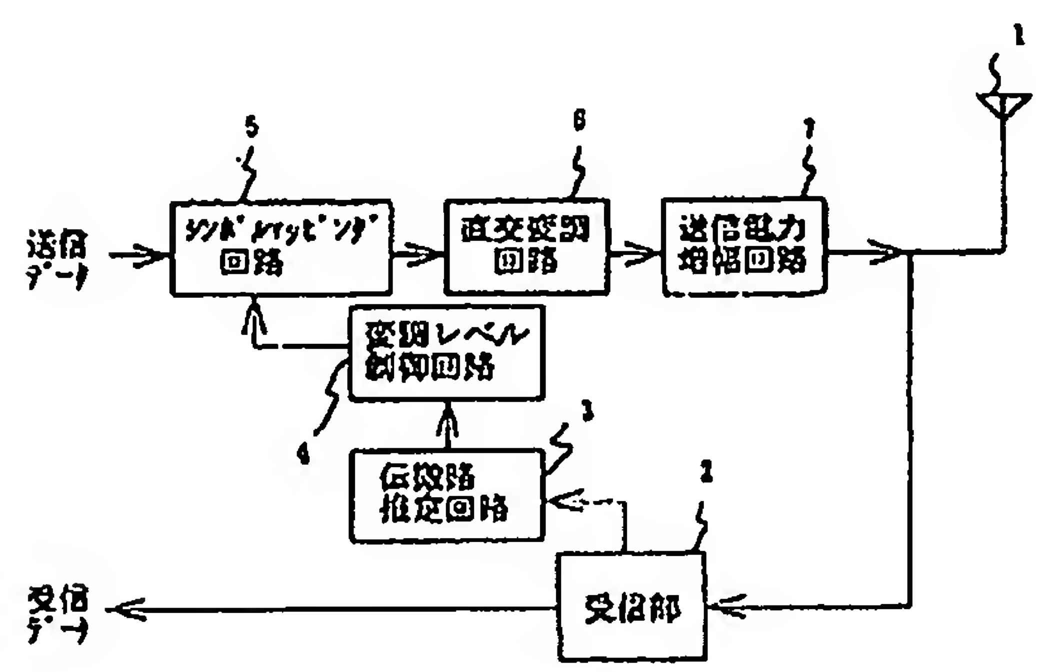
【符号の説明】

1 送信アンテナ
2 受信部
3 伝搬路推定回路
4 変調レベル制御回路
5 シンボルマッピング回路
6 直交変調回路
7 送信電力増幅回路
14 制御回路
17 送信電力増幅回路

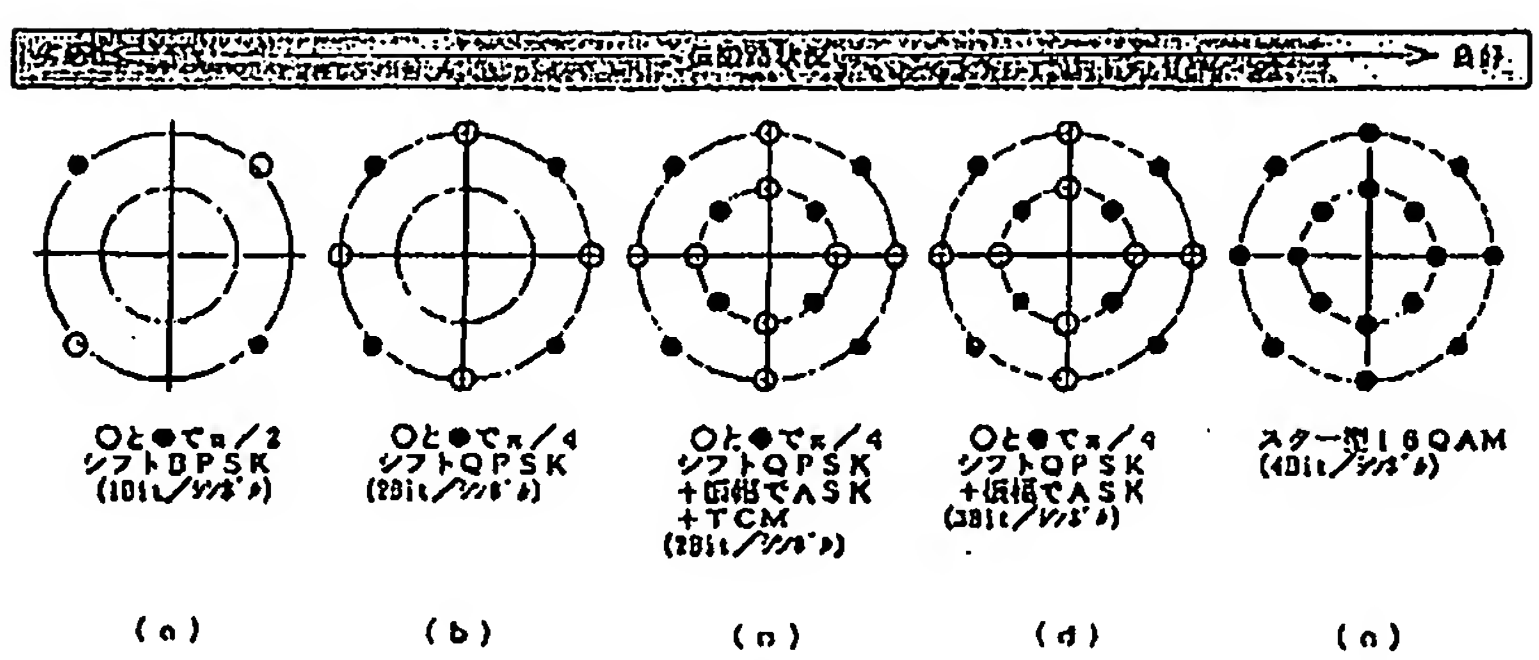
【図1】



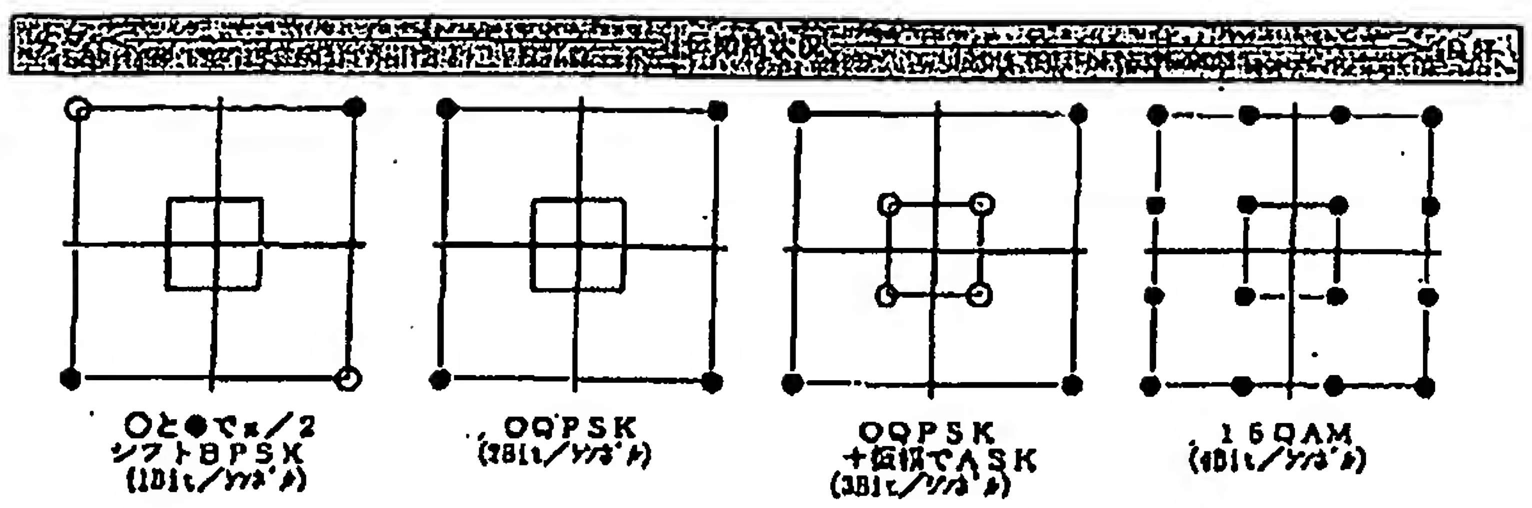
【図4】



【図2】

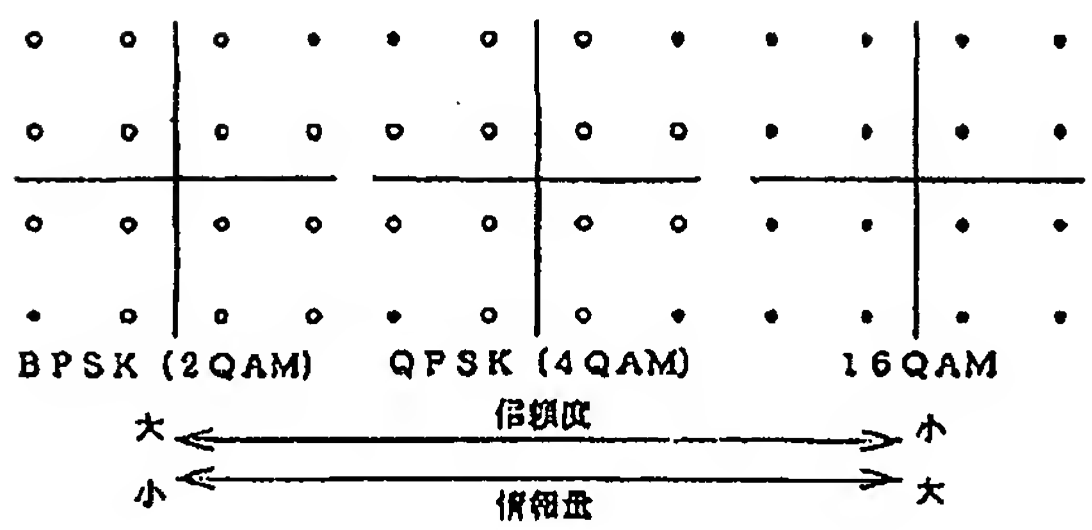


【図3】

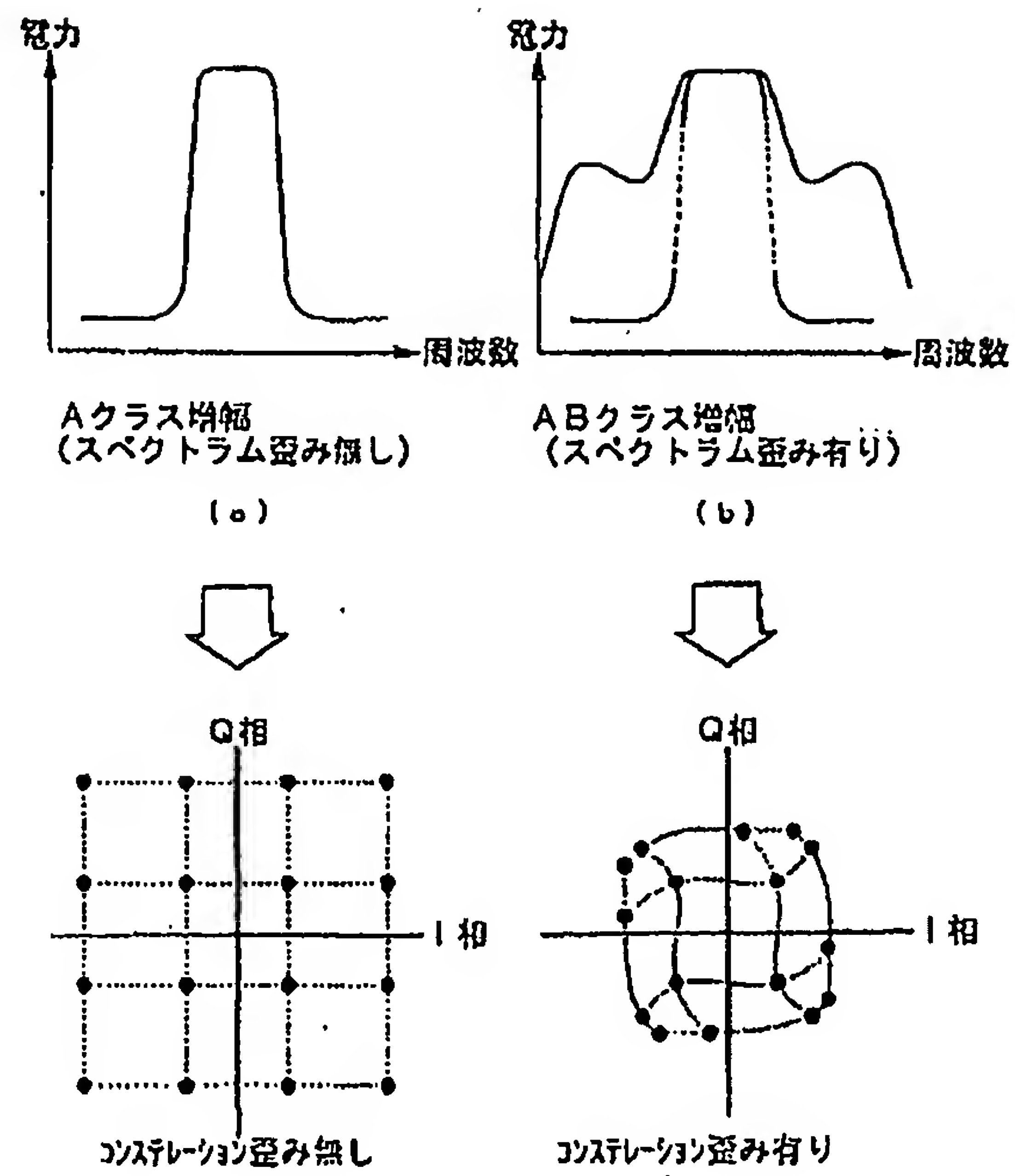

○と●でπ/2
シフトBPSK
(1Bit/シンボル)
OQPSK
(2Bit/シンボル)
OQPSK
＋振幅でASK
(3Bit/シンボル)
16QAM
(4Bit/シンボル)

(a)　(b)　(c)　(d)

【図5】


BPSK (2QAM)
QPSK (4QAM)
16QAM
大
信頼度
小
小
情報量
大

【図6】


電力
周波数
Aクラス増幅
(スペクトラム歪み無し)
(a)
電力
周波数
ABクラス増幅
(スペクトラム歪み有り)
(b)
Q相
I相
コンステレーション歪み無し
(c)
Q相
I相
コンステレーション歪み有り
(d)

【公報種別】特許法第１７条の２の規定による補正の掲載
【部門区分】第７部門第３区分
【発行日】平成１４年１２月２０日（２００２．１２．２０）

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【年通号数】公開特許公報９－８３６
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H04L 27/34
H04B 7/26
H04L 27/02
27/18
【ＦＩ】
H04L 27/00 E
27/02 Z
27/18 Z
H04B 7/26 C

【手続補正書】
【提出日】平成１４年９月３日（２００２．９．３）
【手続補正１】
【補正対象書類名】明細書
【補正対象項目名】特許請求の範囲
【補正方法】変更
【補正内容】
【特許請求の範囲】
【請求項１】 伝搬路状況に応じて、変調多値数の異なる複数の変調方式のいずれかを選択し、選択した変調方式での変調動作を行なう多値適応変調無線装置において、送信データを指定された変調多値数の変調方式のシンボルにマッピングして、対応する複素ベースバンド信号を送出するシンボルマッピング回路と、上記シンボルマッピング回路よりの複素ベースバンド信号に基づき、直交変調を行なう直交変調回路と、上記直交変調回路よりの変調波の電力増幅を、指定されたバックオフで行なう送信電力増幅回路と、受信信号に対して検波および復号の処理を加えて受信データを得て、この受信データを出力する受信回路と、上記受信回路から受信ベースバンド信号若しくは受信レベル情報の一方、又はそれら両方を取込み、この取込んだ信号に基づき、伝搬路状況を推定して、推定結果である推定信号を送出する伝搬路推定回路と、上記伝搬路推定回路よりの推定信号に基づいて前記シンボルマッピング回路と送信電力増幅回路を制御する制御回路とを備え、上記制御回路は、前記推定結果により伝搬路状況が任意に定めた基準値より悪い場合は、上記シンボルマッピング回路に対して、変調多値数が任意の数値以下で且つコンステレーションの零点を交差しない変調方式を指定すると共に、上記送信電力増幅回路に対して、飽和領域を含むバックオフ動作を行う増幅手段を指定し、他方、上記推定結果により伝搬路状況が前記任意に定めた基準値以上の場合は、上記シンボルマッピング回路に対して、変調多値数が前記任意の数値を越える変調方式を指定すると共に、上記送信電力増幅回路に対して、線形領域のみを利用するバックオフ動作を行う増幅手段を指定することを特徴とする多値適応変調無線装置。
【請求項２】 上記制御回路は、変調多値数が任意の数値以下の変調方式としては、π／２シフトＢＰＳＫ又はπ／４シフトＱＰＳＫを選択的に指定し、変調多値数が任意の数値を越える変調方式としては、π／４シフトＱＰＳＫとＡＳＫとを組合わせた方式又はスター１６ＱＡＭを選択的に指定する回路であることを特徴とする請求項１記載の多値適応変調無線装置。
【請求項３】 上記制御回路は、変調多値数が任意の数値を越える変調方式の１つとしてπ／４シフトＱＰＳＫとＡＳＫとトレリス符号化変調とを組合わせた変調方式をも指定する回路であることを特徴とする請求項２記載の多値適応変調無線装置。
【請求項４】 上記制御回路は、変調多値数が任意の数値以下の変調方式としては、π／２シフトＢＰＳＫ又はＯＱＰＳＫを選択的に指定し、変調多値数が任意の数値を越える変調方式としては、ＯＱＰＳＫとＡＳＫを組合わせた方式又は１６ＱＡＭを選択的に指定する回路であることを特徴とする請求項１記載の多値適応変調無線装置。
【手続補正２】
【補正対象書類名】明細書
【補正対象項目名】００１０
【補正方法】変更

【補正内容】
【0010】
【課題を解決するための手段】　本発明では、伝搬路状況に応じて変調多値数の異なる複数の変調方式のいずれかを選択し、選択した変調方式での変調動作を行う多値適応変調無線装置を以下のように構成した。
【手続補正3】
【補正対象書類名】明細書
【補正対象項目名】００１１
【補正方法】変更
【補正内容】
【００１１】　請求項１の発明では、送信データを指定された変調多値数の変調方式のシンボルにマッピングして、対応する複素ベースバンド信号を送出するシンボルマッピング回路と、上記シンボルマッピング回路よりの複素ベースバンド信号に基づき、直交変調を行なう直交変調回路と、上記直交変調回路よりの変調波の電力増幅を、指定されたバックオフで行なう送信電力増幅回路と、受信信号に対して検波および復号の処理を加えて受信データを得て、この受信データを出力する受信回路と、上記受信回路から受信ベースバンド信号若しくは受信レベル情報の一方、又はそれら両方を取込み、この取込んだ信号に基づき、伝搬路状況を推定して、推定結果である推定信号を送出する伝搬路推定回路と、上記伝搬路推定回路よりの推定信号に基づいて前記シンボルマッピング回路と送信電力増幅回路を制御する制御回路とを備え、上記制御回路は、前記推定結果により伝搬路状況が任意に定めた基準値より悪い場合は、上記シンボルマッピング回路に対して、変調多値数が任意の数値以下で且つコンステレーションの零点を交差しない変調方式を指定すると共に、上記送信電力増幅回路に対して、飽和領域を含むバックオフ動作を行う増幅手段を指定し、他方、上記推定結果により伝搬路状況が前記任意に定めた基準値以上の場合は、上記シンボルマッピング回路に対して、変調多値数が前記任意の数値を越える変調方式を指定すると共に、上記送信電力増幅回路に対して、線形領域のみを利用するバックオフ動作を行う増幅手段を指定する構成とした。また、前記変調多値数の任意の数値を「４」として変調方式の指定を行うようにした。

PCT

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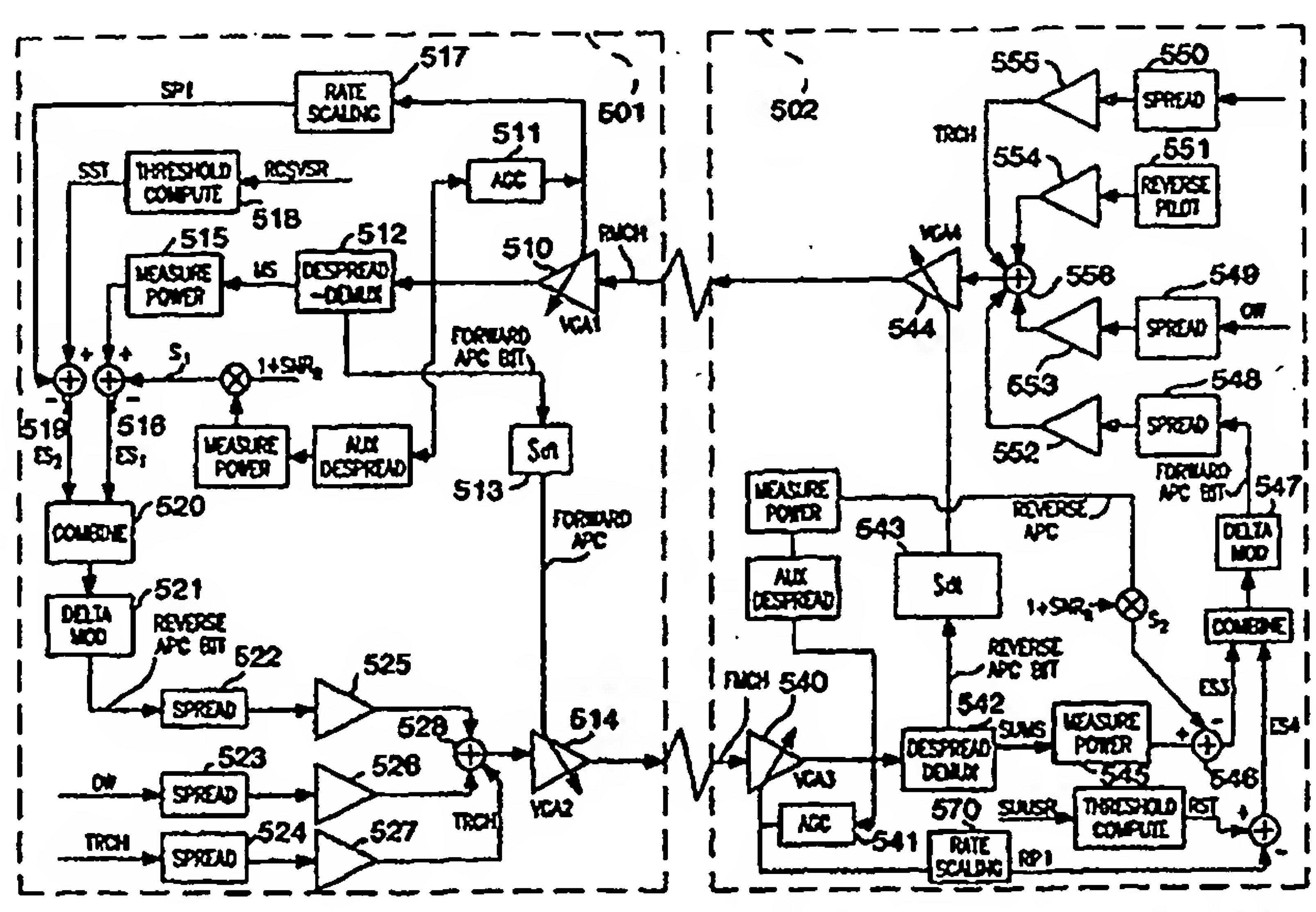
(54) Title: AUTOMATIC POWER CONTROL SYSTEM FOR A CODE DIVISION MULTIPLE ACCESS (CDMA) COMMUNICATIONS SYSTEM



(57) Abstract

An automatic power control (APC) system for a spread-spectrum communications system includes an automatic forward power control (AFPC) system, and an automatic reverse power control (ARPC) system. In the AFPC, each subscriber unit (SU) measures a forward signal-to-noise ratio of a respective forward channel information signal to generate a respective forward channel error signal which includes a measure of the uncorrelated noise in the channel and a measure of the error between the respective forward signal-to-noise ration and a pre determined signal-to-noise value. A control signal generated from the respective forward channel error signal is transmitted as part of a respective reverse channel information signal. A base unit includes AFPC receivers which receive respective reverse channel information signals and extract the forward channel error signals therefrom to adjust the power levels of the respective forward spread-spectrum signals. In the ARPC system, each base measures a reverse signal-to-noise ratio of each of the respective reverse channel information signals and generates a respective reverse channel error signal which includes a measure of the uncorrelated noise in the channel and a measure of the error between the respective reverse signal-to-noise ratio and a pre determined signal-to-noise value. The base unit transmits a control signal generated from the respective reverse channel error signal as a part of a respective forward channel information signal. Each SU includes an ARPC receiver which receives the forward channel information signal and extracts the respective reverse error signal to adjust the reverse transmit power level of the respective reverse spread-spectrum signal.

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AUTOMATIC POWER CONTROL SYSTEM FOR A CODE DIVISION MULTIPLE ACCESS (CDMA) COMMUNICATIONS SYSTEM

BACKGROUND OF THE INVENTION

Providing quality telecommunication services to user groups which are classified as remote, such as rural telephone systems and telephone systems in developing countries, has proved to be a challenge over recent years. These needs have been partially satisfied by wireless radio services, such as fixed or mobile frequency division multiplex (FDM), frequency division multiple access (FDMA), time division multiplex (TDM), time division multiple access (TDMA) systems, combination frequency and time division systems (FD/TDMA), and other land mobile radio systems. Usually, these remote services are faced with more potential users than can be supported simultaneously by their frequency or spectral bandwidth capacity.

Recognizing these limitations, recent advances in wireless communications have used spread spectrum modulation techniques to provide simultaneous communication by multiple users through a single communications channel. Spread spectrum modulation refers to modulating a information signal with a spreading code signal; the spreading code signal being generated by a code generator where the period Tc of the spreading code is substantially less than the period of the information data bit or symbol signal. The code may modulate the carrier frequency upon which the information has been sent, called frequency-hopped spreading, or may directly modulate the signal by multiplying the spreading code with the information data signal, called direct-sequence spreading (DS). Spread-spectrum modulation produces a signal having a bandwidth that is substantially greater than that required to transmit the information signal. Synchronous reception and despreading of the signal at the receiver demodulator recovers the original information. The synchronous demodulator uses a reference signal to synchronize the despreading circuits to the input spread-spectrum modulated signal to recover the carrier and

information signals. The reference signal can be a spreading code which is not modulated by an information signal.

Spread-spectrum modulation in wireless networks offers many advantages because multiple users may use the same frequency band with minimal interference to each user's receiver. In addition, spread spectrum modulation reduces effects from other sources of interference. Also, synchronous spread-spectrum modulation and demodulation techniques may be expanded by providing multiple message channels for a user, each spread with a different spreading code, while still transmitting only a single reference signal to the user.

Another problem associated with multiple access, spread-spectrum communication systems is the need to reduce the total transmitted power of users in the system, since users may have limited available power. An associated problem requiring power control in spread-spectrum systems is related to the inherent characteristic of spread-spectrum systems that one user's spread-spectrum signal is received by another user as noise with a certain power level. Consequently, users transmitting with high levels of signal power may interfere with other users' reception. Also, if a user moves relative to another user's geographic location, signal fading and distortion require that the users adjust their transmit power level to maintain a particular signal quality, and to maintain the power that the base station receives from all users. Finally, because it is possible for the spread-spectrum system to have more remote users than can be supported simultaneously, the power control system should also employ a capacity management method which rejects additional users when the maximum system power level is reached.

Prior spread-spectrum systems have employed a base station that measures a received signal and sends an adaptive power control (APC) signal to the remote users. Remote users include a transmitter with an automatic gain control (AGC) circuit which responds to the APC signal. In such systems the base station monitors the overall system power or the power received from each user, and sets the APC signal accordingly. This open loop system performance may be improved by including a measurement of the signal power received by the remote user from the base station, and transmitting an APC signal back to the base station to effectuate a closed loop power control method.

These power control systems, however, exhibit several disadvantages. First, the base station must perform complex power control algorithms, increasing the amount of processing in the base station. Second, the system actually experiences several types of power variation: variation in the noise power caused by changing numbers of users and variations in the received signal power of a particular bearer channel. These variations occur with different frequency, so simple power control algorithms can be optimized only to one of the two types of variation. Finally, these power algorithms tend to drive the overall system power to a relatively high level. Consequently, there is a need for a spread-spectrum power control method that rapidly responds to changes in bearer channel power levels, while simultaneously making adjustments to all users' transmit power in response to changes in the number of users. Also, there is a need for an improved spread-spectrum communication system employing a closed loop power control system which minimizes the system's overall power requirements while maintaining a sufficient BER at the individual remote receivers. In addition, such a system should control the initial transmit power level of a remote user and manage total system capacity.

SUMMARY OF THE INVENTION

The present invention includes a system and method for closed loop automatic power control (APC) for a base radio carrier station (RCS) and a group of subscriber units (SUs) of a spread-spectrum communication system. The SUs transmit spread-spectrum signals, the RCS acquires the spread-spectrum signals, and the RCS detects the received power level of the spread-spectrum signals plus any interfering signal including noise. The APC system includes the RCS and a plurality of SUs, wherein the RCS transmits a plurality of forward channel information signals to the SUs as a plurality of forward channel spread-spectrum signals having a respective forward transmit power level, and each SU transmits to the base station at least one reverse spread-spectrum signal having a respective reverse transmit power level and at least one reverse channel spread-spectrum signal includes a reverse channel information signal.

The APC includes an automatic forward power control (AFPC) system, and an automatic reverse power control (ARPC) system. The AFPC has the steps of each SU measuring a forward signal-to-noise ratio of the respective forward channel information

signal, generating a respective forward channel error signal which includes a measure of the forward error between the respective forward signal-to-noise ratio and a pre-determined signal-to-noise value. The forward channel error signal also includes a measure of the uncorrelated noise in the channel. The respective forward channel error signal is transmitted by the SU as part of a respective reverse channel information signal. The RCS includes a plural number of AFPC receivers for receiving the reverse channel information signals and extracting the forward channel error signals from the respective reverse channel information signals.The RCS also adjusts the respective forward transmit power level of each one of the respective forward spread-spectrum signals responsive to the respective forward error signal.

The portion of the ARPC system in the RCS measures a reverse signal-to-noise ratio of each of the respective reverse channel information signals, generates a respective reverse channel error signal which includes a measure of the error between the respective reverse channel signal-to-noise ratio and a respective pre-determined signal-to-noise value. The reverse channel error signal also includes a measure of the uncorrelated noise in the channel. The RCU transmits the respective reverse channel error signal as a part of a respective forward channel information signal. Each SU includes an ARPC receiver which receives the forward channel information signal, extracts the respective reverse error signal from the forward channel information signal, and adjusts the reverse transmit power level of the respective reverse spread-spectrum signal responsive to the respective reverse error signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of a code division multiple access communication system according to the present invention.

Figure 2 is a flow-chart diagram of an exemplary maintenance power control algorithm of the present invention.

Figure 3 is a flow-chart diagram of an exemplary automatic forward power control algorithm of the present invention.

Figure 4 is a flow-chart diagram of an exemplary automatic reverse power control algorithm of the present invention.

Figure 5 is a block diagram of an exemplary closed loop power control system of the present invention when the bearer channel is established.

Figure 6 is a block diagram of an exemplary closed loop power control system of the present invention during the process of establishing the bearer channel.

DESCRIPTION OF THE EXEMPLARY EMBODIMENT

The system of the present invention provides local-loop telephone service using radio link between one or more base stations and multiple remote subscriber units. In the exemplary embodiment, one radio link is described for a base station communicating with a fixed subscriber unit (FSU), but the system is equally applicable to systems including multiple base stations with radio links to both FSUs and Mobile Subscriber Units (MSUs). Consequently, the remote subscriber units are referred to herein as Subscriber Units (SUs).

Referring to Figure 1, Base Station (BS) 101 provides call connection to a local exchange (LE) 103 or any other telephone network switching interface, and includes a Radio Carrier Station (RCS) 104. One or more RCSs 104, 105, 110 connect to a Radio Distribution Unit (RDU) 102 through links 131, 132, 137, 138, 139, and RDU 102 interfaces with LE 103 by transmitting and receiving call set-up, control, and information signals through telco links 141, 142, 150. SUs 116, 119 communicate with the RCS 104 through RF links 161, 162, 163, 164, 165. Alternatively, another embodiment of the invention includes several SUs and a "master" SU with functionality similar to the RCS. Such an embodiment may or may not have connection to a local telephone network.

Although the described embodiment uses different spread-spectrum bandwidths centered around a carrier for the transmit and receive spread-spectrum channels, the present method is readily extended to systems using multiple spread-spectrum bandwidths for the transmit channels and multiple spread-spectrum bandwidths for the receive channels. Alternatively, because spread-spectrum communication systems have the inherent feature that one user's transmission appears as noise to another user's

despreading receiver, an embodiment can employ the same spread-spectrum channel for both the transmit and receive path channels. In other words, Uplink and Downlink transmissions can occupy the same frequency band. An embodiment of the invention may also employ multiple spread spectrum channels which need not be adjacent in frequency. In this embodiment, any channel may be used for Uplink, Downlink or Uplink and Downlink transmission.

In the exemplary embodiment, the spread binary symbol information is transmitted over the radio links 161 to 165 using Quadrature Phase Shift Keying (QPSK) modulation with Nyquist Pulse Shaping, although other modulation techniques may be used, including, but not limited to, Offset QPSK (OQPSK), Minimum Shift Keying (MSK), M-ary Phase Shift Keying (MPSK) and Gaussian Phase Shift Keying (GPSK).

The CDMA demodulator in either the RCS or the SU despreads the received signal with appropriate processing to combat or exploit multipath propagation effects. Parameters concerning the received power level are used to generate the Automatic Power Control (APC) information which, in turn, is transmitted to the other end. The APC information is used to control transmit power of the automatic forward power control (AFPC) and automatic reverse power control (ARPC) links. In addition, each RCS 104, 105 and 110 can perform Maintenance Power Control (MPC), in a manner similar to APC, to adjust the initial transmit power of each SU 111, 112, 115, 117 and 118. Demodulation is coherent where the pilot signal provides the phase reference.

The transmit power levels of the radio interface between RCS 104 and SUs 111, 112, 115, 117 and 118 are controlled using two different closed loop power control algorithms. The Automatic Forward Power Control (AFPC) determines the Downlink transmit power level, and the Automatic Reverse Power Control (ARPC) determines the Uplink transmit power level. The logical control channel by which SU 111 and RCS 104, for example, transfer power control information operates at least a 16 kHz update rate. Other embodiments may use a faster 32 kHz update rate. These algorithms ensure that the transmit power of a user maintains an acceptable Bit-Error Rate (BER), maintains the

system power at a minimum to conserve power, and maintains the power level of all SUs 111, 112, 115, 117 and 118, as received by RCS 104, at a nearly equal level.

In addition, the system includes an optional maintenance power algorithm that is used during the inactive mode of a SU. When SU 111 is inactive or powered-down to conserve power, the unit may occasionally activate itself and adjust its initial transmit power level setting in response to a maintenance power control signal from RCS 104. The maintenance power signal is determined by the RCS 104 by measuring the received power level of SU 111 and present system power level and calculating the necessary initial transmit power. The method shortens the channel acquisition time of SU 111 when it is turned on to begin a communication.The method also prevents the transmit power level of SU 111 from becoming too high and interfering with other channels during the initial transmission before the closed loop power control adjusts the transmit power to a level appropriate for the other message traffic in the channel.

The RCS 104 obtains synchronization of its clock from an interface line such as, but not limited to, E1, T1, or HDSL interfaces. Each RCS can also generate its own internal clock signal from an oscillator which may be regulated by a Global Positioning System (GPS) receiver. The RCS 104 generates a Global Pilot Code for a channel having a spreading code but no data modulation, which can be acquired by remote SUs 111 through 118. All transmission channels of the RCS are synchronous with the Pilot channel, and spreading code phases of code generators (not shown) used for Logical communication channels within RCS 104 are also synchronous with the Pilot channel's spreading code phase. Similarly, SUs 111 through 118 which receive the Global Pilot Code of RCS 104 synchronize the spreading and de-spreading code phases of the code generators (not shown) of the SUs to the Global Pilot Code.

Logical Communication Channels

A 'channel' of the prior art is usually regarded as a communications path that is part of an interface and that can be distinguished from other paths of the interface without regard to its content. In the case of CDMA, however, separate communications paths are distinguished only by their content. The term 'logical channel' is used to distinguish the separate data streams, which are logically equivalent to channels in the

conventional sense. All logical channels and sub-channels of the present invention are mapped to a common 64 kilo-symbols per second (ksym/s) QPSK stream. Some channels are synchronized to associated pilot codes which are generated and perform a similar function to the system Global Pilot Code. The system pilot signals are not, however, considered logical channels.

Several logical communication channels are used over the RF communication link between the RCS and SU. Each logical communication channel either has a fixed, pre-determined spreading code or a dynamically assigned spreading code. For both pre-determined and assigned codes, the code phase is synchronous with the Pilot Code. Logical communication channels are divided into two groups: the Global Channel (GC) group and the Assigned Channel (AC) group. The GC group includes channels which are either transmitted from the base station RCS to all the remote SUs or from any SU to the RCS of the base station regardless of the SU's identity. These channels typically contain information of a given type for all users. These channels include the channels used by the SUs to gain system access. Channels in the Assigned Channels (AC) group are those channels dedicated to communication between the RCS and a particular SU.

POWER CONTROL

General

The power control feature of the present invention is used to minimize the transmit power used between an RCS and any SUs with which it is in communication. The power control subfeature that updates transmit power during bearer channel connection is defined as automatic power control (APC). APC data is transferred from the RCS to an SU on the forward APC channel and from an SU to the RCS on the reverse APC channel. When there is no active data link between the two, the maintenance power control subfeature (MPC) controls the transmit power of the SU.

Transmit power levels of forward and reverse assigned channels and reverse global channels are controlled by the APC algorithm to maintain sufficient signal power to interference noise power ratio (SIR) on those channels, and to stabilize and minimize system output power. The present invention uses a closed loop power control system in which a receiver controls its associated transmitter to incrementally raise or lower its transmit power. This control is conveyed to the associated transmitter via the power control signal on the APC channel. The receiver makes the decision to increase or decrease the transmitter's power based on two error signals. One error signal is an indication of the difference between the measured and required despread signal powers, and the other error signal is an indication of the average received total power.

As used in the described embodiment of the invention, the term *near-end* power control is used to refer to adjusting the transmitter's output power in accordance with the APC signal received on the APC channel from the other end. This means the reverse power control for the SU and forward power control for the RCS; and the term *far-end* APC is used to refer to forward power control for the SU and reverse power control for the RCS (adjusting the transmit power of the unit at the opposite end of the channel).

In order to conserve power, the SU modem terminates transmission and powers-down while waiting for a call, defined as the sleep phase. Sleep phase is terminated by an awaken signal from the SU controller. Responsive to this signal, the SU modem acquisition circuit automatically enters the reacquisition phase, and begins the process of acquiring the downlink pilot, as described below.

Closed Loop Power Control Algorithms

The near-end power control includes two steps: first, set the initial transmit power; second, continually adjust transmit power according to information received from the far-end using APC.

For the SU, initial transmit power is set to a minimum value and then ramped up, for example, at a rate of 1 dB/ms until either a ramp-up timer expires (not shown) or the RCS changes the corresponding traffic light value on the FBCH to "red" indicating the RCS has locked to the SU's short pilot signal (SAXPT). Expiration of the timer causes the SAXPT transmission to be shut down, unless the traffic light value is set to red first,

in which case the SU continues to ramp-up transmit power but at a much lower rate than before the "red" signal was detected.

For the RCS, initial transmit power is set at a fixed value, corresponding to the minimum value necessary for reliable operation as determined experimentally for the service type and the current number of system users. Global channels, such as the Global Pilot or, the fast broadcast channel (FBCH), are always transmitted at the fixed initial power, whereas traffic channels are switched to APC.

The APC signal is transmitted as one bit signals on the APC channel. The one-bit signal represents a command to increase (signal is logic-high) or decrease (signal is logic-low) the associated transmit power. In the described embodiment, the 64 kbps APC data stream is not encoded or interleaved.

Far-end power control consists of the near-end transmitting power control information for the far-end to use in adjusting its transmit power.

The APC algorithm causes the RCS or the SU to transmit +1 if the following inequality holds, otherwise -1 (logic-low).

$$\alpha_1 e_1 - \alpha_2 e_2 > 0 \qquad (1)$$

Here, the error signal e_1 is calculated as

$$e_1 = P_d - (1 + SNR_{REF}) P_N \qquad (2)$$

where P_d is the despread signal plus noise power, P_N is the despread noise power, and SNR_{REF} is the desired despread signal to noise ratio for the particular service type; and

$$e_2 = P_r - P_o \qquad (3)$$

where Pr is a measure of the received power and Po is the automatic gain control (AGC) circuit set point. The weights α_1 and α_2 in equation (30) are chosen for each service type and for the APC update rate.

Maintenance Power Control

During the sleep phase of the SU, the interference noise power of the CDMA RF channel changes. As an alternative to the initial power ramp-up method described above, the present invention may include a maintenance power control feature (MPC) which

periodically adjusts the SU's initial transmit power with respect to the interference noise power of the CDMA channel. The MPC is the process whereby the transmit power level of an SU is maintained within close proximity of the minimum level required for the RCS to detect the SU's signal. The MPC process compensates for low frequency changes in the required SU transmit power.

The maintenance control feature uses two global channels: one is called the status channel (STCH) on reverse link, and the other is called the check-up channel (CUCH) on forward link. The signals transmitted on these channels carry no data and they are generated the same way the short codes used in initial power ramp-up are generated. The STCH and CUCH codes are generated from a "reserved" branch of the global code generator.

The MPC process is as follows. At random intervals, the SU sends a symbol length spreading code periodically for 3 ms on the status channel (STCH). If the RCS detects the sequence, it replies by sending a symbol length code sequence within the next 3 ms on the check-up channel (CUCH). When the SU detects the response from the RCS, it reduces its transmit power by a particular step size. If the SU does not detect any response from the RCS within the 3 ms period, it increases its transmit power by the step size. Using this method, the RCS response is transmitted at a power level that is enough to maintain a 0.99 detection probability at all SU's.

The rate of change of traffic load and the number of active users is related to the total interference noise power of the CDMA channel. The update rate and step size of the maintenance power update signal for the present invention is determined by using queuing theory methods well known in the art of communication theory. By modeling the call origination process as an exponential random variable with mean 6.0 mins, numerical computation shows the maintenance power level of a SU should be updated once every 10 seconds or less to be able to follow the changes in interference level using 0.5 dB step size. Modeling the call origination process as a Poisson random variable with exponential interarrival times, arrival rate of $2x10^{-4}$ per second per user, service rate of 1/360 per second, and the total subscriber population is 600 in the RCS service area also yields by

numerical computation that an update rate of once every 10 seconds is sufficient when 0.5 dB step size is used.

Maintenance power adjustment is performed periodically by the SU which changes from sleep phase to awake phase and performs the MPC process. Consequently, the process for the MPC feature is shown in Figure 2 and is as follows: First, at step 201, signals are exchanged between the SU and the RCS maintaining a transmit power level that is close to the required level for detection: the SU periodically sends a symbol length spreading code in the STCH, and the RCS sends periodically a symbol length spreading code in the CUCH as response.

Next, at step 202, if the SU receives a response within 3 ms after the STCH message it sent, it decreases its transmit power by a particular step size at step 203; but if the SU does not receive a response within 3 ms after the STCH message, it increases its transmit power by the same step size at step 204.

The SU waits, at step 205, for a period of time before sending another STCH message, this time period is determined by a random process which averages 10 seconds.

Thus, the transmit power of the STCH messages from the SU is adjusted based on the RCS response periodically, and the transmit power of the CUCH messages from the RCS is fixed.

Mapping of Power Control Signal to Logical Channels For APC

Power control signals are mapped to specified Logical Channels for controlling transmit power levels of forward and reverse assigned channels. Reverse global channels are also controlled by the APC algorithm to maintain sufficient signal power to interference noise power ratio (SIR) on those reverse channels, and to stabilize and minimize system output power. The present invention uses a closed loop power control method in which a receiver periodically decides to incrementally raise or lower the output power of the transmitter at the other end. The method also conveys that decision back to the respective transmitter.

Table 1: APC Signal Channel Assignments

Link Channels and Signals	Call/Connection Status	Power Control Method	
		Initial Value	Continuous
Reverse link AXCH AXPT	Being Established	as determined by power ramping	APC bits in forward APC channel
Reverse link APC, OW, TRCH, pilot signal	In-Progress	level established during call set-up	APC bits in forward APC channel
Forward link APC, OW, TRCH	In-Progress	fixed value	APC bits in reverse APC channel

Forward and reverse links are independently controlled. For a call/connection in process, forward link traffic channel (TRCH) APC, and Order Wire (OW) power is controlled by the APC bits transmitted on the reverse APC channel. During the call/connection establishment process, reverse link access channel (AXCH) power is also controlled by the APC bits transmitted on the forward APC channel. Table 11 summarizes the specific power control methods for the controlled channels.

The required SIRs of the assigned channels TRCH, APC and OW and reverse assigned pilot signal for any particular SU are fixed in proportion to each other and these channels are subject to nearly identical fading, therefore, they are power controlled together.

Automatic Forward Power Control

The AFPC system attempts to maintain the minimum required SIR on the forward channels during a call/connection. The AFPC recursive process shown in Figure 3 consists of the steps of having an SU form the two error signals e_1 and e_2 in step 301 where

$$e_1 = P_d - (1 + SNR_{REF}) P_N \tag{4}$$

$$e_2 = P_r - P_o \tag{5}$$

and P_d is the despread signal plus noise power, P_N is the despread noise power, SNR_{REF} is the required signal to noise ratio for the service type, P_r is a measure of the total received power, and P_o is the AGC set point. Next, the SU modem forms the combined error signal $\alpha_1 e_1 + \alpha_2 e_2$ in step 302. Here, the weights α_1 and α_2 are chosen for each service type and APC update rate. In step 303, the SU hard limits the combined error signal and forms a single APC bit. The SU transmits the APC bit to the RCS in step 304 and RCS modem receives the bit in step 305. The RCS increases or decreases its transmit power to the SU in step 306 and the algorithm repeats starting from step 301.

Automatic Reverse Power Control

The ARPC system maintains the minimum required SIR on the reverse channels to minimize the total system reverse output power, during both call/connection establishment and while the call/connection is in progress. The ARPC recursive process shown in Figure 4 begins at step 401 where the RCS modem forms the two error signals e_1 and e_2 in step 401 where

$$e_1 = P_d - (1 + SNR_{REF}) P_N \tag{6}$$

$$e_2 = P_{rt} - P_o \tag{7}$$

and P_d is the despread signal plus noise power, P_N is the despread noise power, SNR_{REF} is the reference signal to noise ratio for the service type, P_{rt} is a measure of the average total power received by the RCS, and P_o is the AGC set point. The RCS modem forms the combined error signal $\alpha_1 e_1 + \alpha_2 e_2$ in step 402 and hard limits this error signal to determine a single APC bit in step 403. The RCS transmits the APC bit to the SU in step 404, and the bit is received by the SU in step 405. Finally, SU adjusts its transmit power

according to the received APC bit in step 406, and the process repeats starting from step 401.

Table 2: Symbols/Thresholds Used for APC Computation

Service or Call Type	Call/Connection Status	Symbol (and Threshold) Used for APC Decision
Don't care	Being Established	AXCH
ISDN D SU	In-Progress	one 1/64-KBPS symbol from TRCH (ISDN-D)
ISDN 1B+D SU	In-Progress	TRCH (ISDN-B)
ISDN 2B+D SU	In-Progress	TRCH (one ISDN-B)
POTS SU (64 KBPS PCM)	In-Progress	one 1/64-KBPS symbol from TRCH, use 64 KBPS PCM threshold
POTS SU (32 KBPS ADPCM)	In-Progress	one 1/64-KBPS symbol from TRCH, use 32 KBPS ADPCM threshold
Silent Maintenance Call (any SU)	In-Progress	OW (continuous during a maintenance call)

SIR and Multiple Channel Types

The required SIR for channels on a link is a function of channel format (e.g. TRCH, OW), service type (e.g. ISDN B, 32 kb/s ADPCM POTS), and the number of symbols over which data bits are distributed (e.g. two 64 kb/s symbols are integrated to form a single 32 kb/s ADPCM POTS symbol). Despreader output power corresponding to the required SIR for each channel and service type is predetermined. While a call/connection is in progress, several user CDMA logical channels are concurrently active; each of these channels transfers a symbol every symbol period. The SIR of the symbol from the nominally highest SIR channel is measured, compared to a threshold and used to determine the APC step up/down decision each symbol period. Table 2 indicates the symbol (and threshold) used for the APC computation by service and call type.

APC Parameters

APC information is always conveyed as a single bit of information, and the APC Data Rate is equivalent to the APC Update Rate. The APC update rate is 64 kb/s. This rate is high enough to accommodate expected Rayleigh and Doppler fades, and allow for a relatively high (~0.2) Bit Error Rate (BER) in the Uplink and Downlink APC channels, which minimizes capacity devoted to the APC.

The power step up/down indicated by an APC bit is nominally between 0.1 and 0.01 dB. The dynamic range for power control is 70 dB on the reverse link and 12 dB on the forward link for the exemplary embodiment of the present system.

An Alternative Embodiment for Multiplexing APC Information

The dedicated APC and OW logical channels described previously can also be multiplexed together in one logical channel. The APC information is transmitted at 64 kb/s. continuously whereas the OW information occurs in data bursts. The alternative multiplexed logical channel includes the unencoded, non-interleaved 64 kb/s. APC information on, for example, the In-phase channel and the OW information on the Quadrature channel of the QPSK signal.

Closed Loop Power Control Implementation

The closed loop power control during a call connection responds to two different variations in overall system power. First, the system responds to local behavior such as changes in power level of an SU, and second, the system responds to changes in the power level of the entire group of active users in the system.

The Power Control system of the exemplary embodiment of the present invention is shown in Figure 5. As shown, the circuitry used to adjust the transmitted power is similar for the RCS (shown as the RCS power control module 501) and SU (shown as the SU power control module 502). Beginning with the RCS power control module 501, the reverse link RF channel signal is received at the RF antenna and demodulated to produce the reverse CDMA signal RMCH which is applied to the variable gain amplifier (VGA1) 510. The output signal of VGA1 510 is provided to the Automatic Gain Control (AGC)

Circuit 511 which produces a variable gain amplifier control signal into the VGA1 510. This signal maintains the level of the output signal of VGA1 510 at a near constant value. The output signal of VGA1 is despread by the despread-demultiplexer (demux) 512, which produces a despread user message signal MS and a forward APC bit. The forward APC bit is applied to the integrator 513 to produce the Forward APC control signal. The Forward APC control signal controls the Forward Link VGA2 514 and maintains the Forward Link RF channel signal at a minimum level necessary for communication.

The signal power of the despread user message signal MS of the RCS power module 501 is measured by the power measurement circuit 515 to produce a signal power indication. The output of the VGA1 is also despread by the AUX despreader which despreads the signal by using an uncorrelated spreading code, and hence obtains a despread noise signal. The power measurement of this signal is multiplied by 1 plus the required signal to noise ratio (SNR_R) to form the threshold signal S1. The difference between the despread signal power and the threshold value S1 is produced by the subtracter 516. This difference is the error signal ES1, which is an error signal relating to the particular SU transmit power level. Similarly, the control signal for the VGA1 510 is applied to the rate scaling circuit 517 to reduce the rate of the control signal for VGA1 510. The output signal of scaling circuit 517 is a scaled system power level signal SP1. The Threshold Compute logic 518 computes the System Signal Threshold SST value from the RCS user channel power data signal (RCSUSR). The complement of the Scaled system power level signal, SP1, and the System Signal Power Threshold value SST are applied to the adder 519 which produces second error signal ES2. This error signal is related to the system transmit power level of all active SUs. The input Error signals ES1 and ES2 are combined in the combiner 520 produce a combined error signal input to the delta modulator (DM1) 521, and the output signal of the DM1 is the reverse APC bit stream signal, having bits of value +1 or -1, which for the present invention is transmitted as a 64kb/sec signal.

The Reverse APC bit is applied to the spreading circuit 522, and the output signal of the spreading circuit 522 is the spread-spectrum forward APC message signal. Forward OW and Traffic signals are also provided to spreading circuits 523, 524, producing forward traffic message signals 1, 2, . . N. The power level of the forward

APC signal, the forward OW, and traffic message signals are adjusted by the respective amplifiers 525, 526 and 527 to produce the power level adjusted forward APC, OW, and TRCH channels signals. These signals are combined by the adder 528 and applied to the VAG2 514, which produces forward link RF channel signal.

The forward link RF channel signal including the spread forward APC signal is received by the RF antenna of the SU, and demodulated to produce the forward CDMA signal FMCH. This signal is provided to the variable gain amplifier (VGA3) 540. The output signal of VGA3 is applied to the Automatic Gain Control Circuit (AGC) 541 which produces a variable gain amplifier control signal to VGA3 540. This signal maintains the level of the output signal of VGA3 at a near constant level. The output signal of VAG3 540 is despread by the despread demux 542, which produces a despread user message signal SUMS and a reverse APC bit. The reverse APC bit is applied to the integrator 543 which produces the Reverse APC control signal. This reverse APC control signal is provided to the Reverse APC VGA4 544 to maintain the Reverse link RF channel signal at a minimum power level.

The despread user message signal SUMS is also applied to the power measurement circuit 545 producing a power measurement signal, which is added to the complement of threshold value S2 in the adder 546 to produce error signal ES3. The signal ES3 is an error signal relating to the RCS transmit power level for the particular SU. To obtain threshold S2, the despread noise power indication from the AUX despreader is multiplied by 1 plus the desired signal to noise ratio SNR_R. The AUX despreader despreads the input data using an uncorrelated spreading code, hence its output is an indication of the despread noise power.

Similarly, the control signal for the VGA3 is applied to the rate scaling circuit to reduce the rate of the control signal for VGA3 in order to produce a scaled received power level RP1 (see Fig. 5). The threshold compute circuit computes the received signal threshold RST from SU measured power signal SUUSR. The complement of the scaled received power level RP1 and the received signal threshold RST are applied to the adder which produces error signal ES4. This error is related to the RCS transmit power to all other SUs. The input error signals ES3 and ES4 are combined in the combiner and input

to the delta modulator DM2 547, and the output signal of DM2 547 is the forward APC bit stream signal, with bits having value of value +1 or -1. In the exemplary embodiment of the present invention, this signal is transmitted as a 64kb/sec signal.

The Forward APC bit stream signal is applied to the spreading circuit 2948, to produce the output reverse spread-spectrum APC signal. Reverse OW and Traffic signals are also input to spreading circuits 549, 550, producing reverse OW and traffic message signals 1, 2, . . N, and the reverse pilot is generated by the reverse pilot generator 551. The power level of the reverse APC message signal, reverse OW message signal, reverse pilot, and the reverse traffic message signals are adjusted by amplifiers 552, 553, 554, 555 to produce the signals which are combined by the adder 556 and input to the reverse APC VGA4 544. It is this VGA4 544 which produces the reverse link RF channel signal.

During the call connection and bearer channel establishment process, the closed loop power control of the present invention is modified, and is shown in Figure 6. As shown, the circuits used to adjust the transmitted power are different for the RCS, shown as the Initial RCS power control module 601; and for the SU, shown as the Initial SU power control module 602. Beginning with the Initial RCS power control module 601, the reverse link RF channel signal is received at the RF antenna and demodulated producing the reverse CDMA signal IRMCH which is received by the first variable gain amplifier (VGA1) 603. The output signal of VGA1 is detected by the Automatic Gain Control Circuit (AGC1) 604 which provides a variable gain amplifier control signal to VGA1 603 to maintain the level of the output signal of VAG1 at a near constant value. The output signal of VGA1 is despread by the despread demultiplexer 605, which produces a despread user message signal IMS. The Forward APC control signal, ISET, is set to a fixed value, and is applied to the Forward Link Variable Gain Amplifier (VGA2) 606 to set the Forward Link RF channel signal at a predetermined level.

The signal power of the despread user message signal IMS of the Initial RCS power module 601 is measured by the power measure circuit 607, and the output power measurement is subtracted from a threshold value S3 in the subtracter 608 to produce error signal ES5, which is an error signal relating to the transmit power level of a particular SU. The threshold S3 is calculated by multiplying the despread power

measurement obtained from the AUX despreader by 1 plus the desired signal to noise ratio SNR_R. The AUX despreader despreads the signal using an uncorrelated spreading code, hence its output signal is an indication of despread noise power. Similarly, the VGA1 control signal is applied to the rate scaling circuit 609 to reduce the rate of the VGA1 control signal in order to produce a scaled system power level signal SP2. The threshold computation logic 610 determines an Initial System Signal Threshold value (ISST) computed from the user channel power data signal (IRCSUSR). The complement of the scaled system power level signal SP2 and the (ISST) are provided to the adder 611 which produces a second error signal ES6, which is an error signal relating to the system transmit power level of all active SUs. The value of ISST is the desired transmit power for a system having the particular configuration. The input Error signals ES5 and ES6 are combined in the combiner 612 produce a combined error signal input to the delta modulator (DM3) 613. DM3 produces the initial reverse APC bit stream signal, having bits of value +1 or -1, which for the present invention is transmitted as a 64kb/sec signal.

The Reverse APC bit stream signal is applied to the spreading circuit 614, to produce the initial spread-spectrum forward APC signal. The control channel (CTCH) information is spread by the spreader 616 to form the spread CTCH message signal. The spread APC and CTCH signals are scaled by the amplifiers 615 and 617, and combined by the combiner 618. The combined signal is applied to VAG2 606, which produces the forward link RF channel signal.

The forward link RF channel signal including the spread forward APC signal is received by the RF antenna of the SU, and demodulated to produce the initial forward CDMA signal (IFMCH) which is applied to the variable gain amplifier (VGA3) 620. The output signal of VGA3 is detected by the Automatic Gain Control Circuit (AGC2) 621 which produces a variable gain amplifier control signal for the VGA3 620. This signal maintains the output power level of the VGA3 620 at a near constant value. The output signal of VAG3 is despread by the despread demultiplexer 622, which produces an initial reverse APC bit that is dependent on the output level of VGA3. The reverse APC bit is processed by the integrator 623 to produce the Reverse APC control signal. The Reverse APC control signal is provided to the Reverse APC VGA4 624 to maintain Reverse link RF channel signal at a defined power level.

The global channel AXCH signal is spread by the spreading circuits 625 to provide the spread AXCH channel signal. The reverse pilot generator 626 provides a reverse pilot signal, and the signal power of AXCH and the reverse pilot signal are adjusted by the respective amplifiers 627 and 628. The spread AXCH channel signal and the reverse pilot signal are added by the adder 629 to produce reverse link CDMA signal. The reverse link CDMA signal is received by the reverse APC VGA4 624, which produces the reverse link RF channel signal output to the RF transmitter.

System Capacity Management

The system capacity management algorithm of the present invention optimizes the maximum user capacity for an RCS area, called a cell. When the SU comes within a certain value of maximum transmit power, the SU sends an alarm message to the RCS. The RCS sets the traffic lights which control access to the system, to "red" which, as previously described, is a flag that inhibits access by the SU's. This condition remains in effect until the alarming SU terminates its call, or until the transmit power of the alarming SU, measured at the SU, is a value less than the maximum transmit power. When multiple SUs send alarm messages, the condition remains in effect until either all calls from alarming SUs terminate, or until the transmit power of the alarming SU, measured at the SU, is a value less than the maximum transmit power. An alternative embodiment measures the bit error rate measurements from the Forward Error Correction (FEC) decoder, and holds the RCS traffic lights at "red" until the bit error rate is less than a predetermined value.

The blocking strategy of the present invention includes a method which uses the power control information transmitted from the RCS to an SU, and the received power measurements at the RCS. The RCS measures its transmit power level, detects that a maximum value is reached, and determines when to block new users. An SU preparing to enter the system blocks itself if the SU reaches the maximum transmit power before successful completion of a bearer channel assignment.

Each additional user in the system has the effect of increasing the noise level for all other users, which decreases the signal to noise ratio (SNR) that each user experiences. The power control algorithm maintains a desired SNR for each user. Therefore, in the

absence of any other limitations, addition of a new user into the system has only a transient effect and the desired SNR is regained.

The transmit power measurement at the RCS is done by measuring either the root mean square (rms) value of the baseband combined signal or by measuring the transmit power of the RF signal and feeding it back to digital control circuits. The transmit power measurement may also be made by the SUs to determine if the unit has reached its maximum transmit power. The SU transmit power level is determined by measuring the control signal of the RF amplifier, and scaling the value based on the service type, such as plain old telephone service (POTS), FAX, or integrated services digital network (ISDN).

The information that an SU has reached the maximum power is transmitted to the RCS by the SU in a message on the Assigned Channels. The RCS also determines the condition by measuring reverse APC changes because, if the RCS sends APC messages to the SU to increase SU transmit power, and the SU transmit power measured at the RCS is not increased, the SU has reached the maximum transmit power.

The RCS does not use traffic lights to block new users who have finished ramping-up using the short codes. These users are blocked by denying them the dial tone and letting them time out. The RCS sends all 1's (go down commands) on the APC Channel to make the SU lower its transmit power. The RCS also sends either no CTCH message or a message with an invalid address which would force the FSU to abandon the access procedure and start over. The SU does not start the acquisition process immediately because the traffic lights are red.

When the RCS reaches its transmit power limit, it enforces blocking in the same manner as when an SU reaches its transmit power limit. The RCS turns off all the traffic lights on the FBCH, starts sending all 1 APC bits (go down commands) to those users who have completed their short code ramp-up but have not yet been given dial tone, and either sends no CTCH message to these users or sends messages with invalid addresses to force them to abandon the access process.

The self blocking algorithm of the SU is as follows. When the SU starts transmitting the AXCH, the APC starts its power control operation using the AXCH and

the SU transmit power increases. While the transmit power is increasing under the control of the APC, it is monitored by the SU controller. If the transmit power limit is reached, the SU abandons the access procedure and starts over.

Although the invention has been described in terms of an exemplary embodiment, it is understood by those skilled in the art that the invention may be practiced with modifications to the embodiment that are within the scope of the invention as defined by the following claims:

The Invention Claimed Is:

1. A automatic power control (APC) system for a multiple access, spread-spectrum communication system, comprising

first and second transceivers, wherein the first transceiver transmits a forward channel information signal to the second transceiver as a forward spread-spectrum signal having a forward transmit power level, and the second transceiver transmits a reverse channel information signal to the first transceiver as a reverse spread-spectrum signal having a reverse transmit power level;

an automatic forward power control (AFPC) system, comprising

a) means in the second transceiver including: received signal measuring means for measuring a forward channel signal-to-noise ratio of the forward channel information signal, error generating means for generating a forward channel error signal corresponding to a difference between the measured forward channel signal-to-noise ratio and a pre-determined signal-to-noise value, and a transmitting means for transmitting the forward channel error signal as a forward error spread-spectrum signal; and

b) means in the first transceiver including: a first receiving means for receiving the forward channel error signal from the forward error spread-spectrum signal, and a first transmit power adjustment means for adjusting the forward transmit power level of the forward spread-spectrum signal responsive to the received forward error signal, and;

an automatic reverse power control (ARPC) system, comprising:

a) means in the first transceiver including: received signal measuring means for measuring a reverse channel signal-to-noise ratio of the reverse channel information signal, error generating means for generating a reverse channel error signal corresponding to a difference between the measured reverse channel signal-to-noise ratio and a pre-determined signal-to-noise value, and a transmitting means for transmitting

the reverse channel error signal as a reverse error spread-spectrum signal; and .

b) means in the second transceiver including: a second receiving means for receiving the reverse error signal from the reverse error spread-spectrum signal, and a second transmit power adjustment means for adjusting the reverse transmit power level of the reverse spread-spectrum signal responsive to the reverse error signal.

2. An APC system as set forth in claim 1 wherein each of the forward error signal and the reverse error signal includes a one-bit signal which indicates whether the respective difference signal is positive or negative.

3. An APC system as set forth in claim 1 wherein each of the forward error signal and the reverse error signal includes a measure of instantaneous noise in the channel.

4. An automatic power control (APC) system for a multiple access, spread-spectrum communication system, comprising

a base station and a plurality of subscriber units, wherein the base station transmits a plurality of forward channel information signals to a plurality of subscriber units as a plurality of forward channel spread-spectrum signals each having a respective forward transmit power level, and each of the subscriber units transmit to the base station at least one reverse spread-spectrum signal having a respective reverse transmit power level and at least one reverse channel spread-spectrum signal includes a reverse channel information signal;

an automatic forward power control (AFPC) system, wherein:

a) each one of the plurality of subscriber units comprises: forward channel signal measuring means for measuring a forward signal-to-noise ratio of the respective forward channel information signal, forward error generating means for generating a respective forward channel error signal corresponding to a difference between the respective measured forward signal-to-noise ratio and a pre-determined signal-to-noise value, and a

transmitting means for transmitting the respective forward channel error signal as part of a respective reverse channel information signal; and

b) the base station comprises: a plurality of AFPC receiving means for receiving the plurality of reverse channel information signals and extracting the plurality of forward channel error signals from the respective reverse channel information signals, and a plurality of forward transmit power adjustment means for adjusting the respective forward transmit power levels of the respective forward spread-spectrum signals responsive to the respective forward error signals, and;

an automatic reverse power control (ARPC) system, wherein:

a) the base station comprises: a plurality of reverse signal measuring means, each reverse signal measuring means for measuring a reverse signal-to-noise ratio of the respective reverse channel information signal; a plurality of reverse error generating means, each reverse error generating means for generating a respective reverse channel error signal representing a difference between the respective measured reverse channel signal-to-noise ratio and a respective pre-determined signal-to-noise value; and a plurality of transmitting means, each transmitting means for transmitting the respective reverse channel error signal as a part of a respective forward channel information signal; and

b) each subscriber unit comprises: an ARPC receiving means for receiving a respective one of the forward channel information signals and extracting the respective reverse error signal from the forward channel information signal, and a subscriber transmit power adjustment means for adjusting the reverse transmit power level of the respective reverse spread-spectrum signal responsive to the respective reverse error signal.

5. An automatic forward power control (AFPC) system for a multiple access, spread-spectrum communication system, comprising

a base station and a plurality of subscriber units, wherein the base station transmits a plurality of forward channel information signals to a plurality of subscriber units as a plurality of forward channel spread-spectrum signals, and each of the subscriber units transmits to the base station at least one reverse spread-spectrum signal, and at least one reverse channel spread-spectrum signal includes a reverse channel information signal;

each one of the plurality of subscriber units comprises: forward channel signal measuring means for measuring a forward signal-to-noise ratio of the respective forward channel information signal, forward error generating means for generating a respective forward channel error signal corresponding to a difference between the respective forward signal-to-noise ratio and a pre-determined signal-to-noise value, and a transmitting means for transmitting the respective forward channel error signal as part of a respective reverse channel information signal; and

the base station comprises: a plurality of AFPC receiving means for receiving the plurality of reverse channel information signals and extracting the plurality of forward channel error signals from the respective reverse channel information signals, and a plurality of forward transmit power adjustment means for adjusting the respective forward transmit power levels of each of the respective forward spread-spectrum signals responsive to the respective forward error signal.

6. An AFPC system as set forth in claim 5 wherein the forward channel error signal includes a one-bit signal which indicates whether the respective difference signal is positive or negative.

7. An AFPC system as set forth in claim 5 wherein the forward channel error signal includes a measure of instantaneous noise in the channel.

8. The AFPC system of claim 7, wherein each of the subscriber units further comprise:

a system noise measuring means for measuring a system noise power level of the spread-spectrum system comprising the plurality of forward spread-spectrum signals;

means for multiplying the difference signal by the measured system noise power level to generate the forward channel error signal.

9. An automatic reverse power control (ARPC) system for a multiple access, spread-spectrum communication system, comprising:

a base station and a plurality of subscriber units, wherein the base station transmits a plurality of forward channel information signals to a plurality of subscriber units as a plurality of forward channel spread-spectrum signals, and each ones of the subscriber units transmit to the base station at least one reverse spread-spectrum signal, and at least one reverse channel spread-spectrum signal includes a reverse channel information signal;

the base station comprises: a plurality of reverse signal measuring means, each reverse signal measuring means for measuring a reverse signal-to-noise ratio of the respective reverse channel information signal; a plurality of reverse error generating means, each reverse error generating means for generating a respective reverse channel error signal representing a difference between the respective reverse channel signal-to-noise ratio and a respective pre-determined signal-to-noise value; and a plurality of transmitting means, each transmitting means for transmitting the respective reverse channel error signal as a part of the respective forward channel information signal; and

each subscriber unit comprises: an ARPC receiving means for receiving a respective one of the forward channel information signals and extracting the respective reverse error signal from the forward channel information signal, and a subscriber transmit power adjustment means for adjusting the reverse transmit power level of the respective reverse spread-spectrum signal responsive to the respective reverse error signal.

10. An ARPC system as set forth in claim 9 wherein the reverse channel error signal includes a one-bit signal which indicates whether the respective difference signal is positive or negative.

11. An AFPC system as set forth in claim 9 wherein the reverse channel error signal includes a measure of instantaneous noise in the channel.

12. The ARPC system of claim 11, wherein the base station of the ARPC system further comprises

a system noise measuring means for measuring a system noise power level of the spread-spectrum system comprising the plurality of reverse spread-spectrum signals;

means for multiplying the difference signal by the measured system noise power level to generate the reverse channel error signal.

13. An automatic maintenance power control (MPC) system for a multiple access, spread-spectrum communication system for maintaining the initial transmit power of a subscriber unit, comprising

a base station and a plurality of inactive subscriber units, wherein the base station transmits a plurality of forward inactive channel information signals to a plurality of subscriber units as a plurality of forward channel spread-spectrum signals, and each of the inactive subscriber units occasionally transmits to the base station at least one reverse spread-spectrum signal including a reverse channel information signal;

the base station comprises:

a) a plurality of reverse signal measuring means, each reverse signal measuring means comprising: means for measuring a reverse signal-to-noise ratio of the respective reverse channel information signal; a plurality of reverse error generating means, each reverse error generating means for generating a respective reverse channel error signal representing a difference between the respective reverse channel signal-to-noise ratio and a respective pre-determined signal-to-noise value;

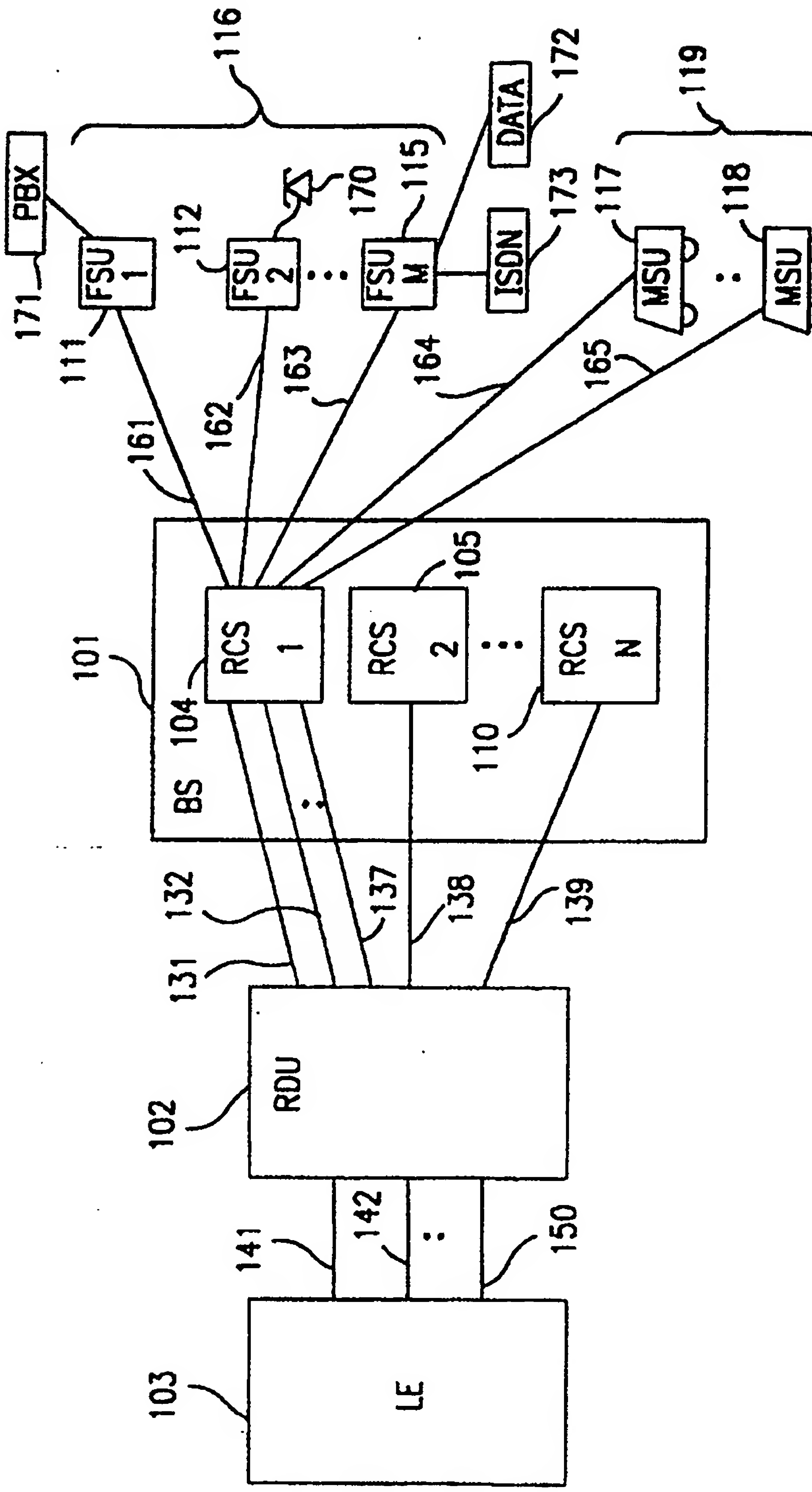
b) a system noise measuring means for measuring a system noise power level of the spread-spectrum system comprising: means for receiving a plurality of reverse spread-spectrum signals; means for combining the received spread spectrum signals with an uncorrelated despreading signal to produce a noise signal; and means for measuring a power level of the noise signal to produce a system noise power signal;

c) means for multiplying the difference signal by the system noise power signal to generate the reverse channel error signal; and

d) a plurality of transmitting means, each transmitting means for transmitting a respective reverse channel error signal as a part of a respective forward channel information signal; and

each subscriber unit comprises an MPC receiving means for receiving a respective one of the forward channel information signals and extracting the respective reverse error signal from the forward channel information signal, and a subscriber transmit power adjustment means for adjusting the reverse transmit power level of the respective reverse spread-spectrum signal responsive to the respective reverse error signal.

14. The automatic maintenance power control (MPC) system of claim 29, further comprising a plurality of active subscriber units each of which transmits substantially continuous active information signals and wherein the plurality of reverse spread-spectrum signals includes the plurality of active information signals.


116
172
DATA
119
PBX
170
115
173
117
118
112
FSU 1
FSU 2
FSU M
ISDN
MSU
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111
161
162
163
164
165
101
BS
104
RCS 1
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RDU
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142
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103
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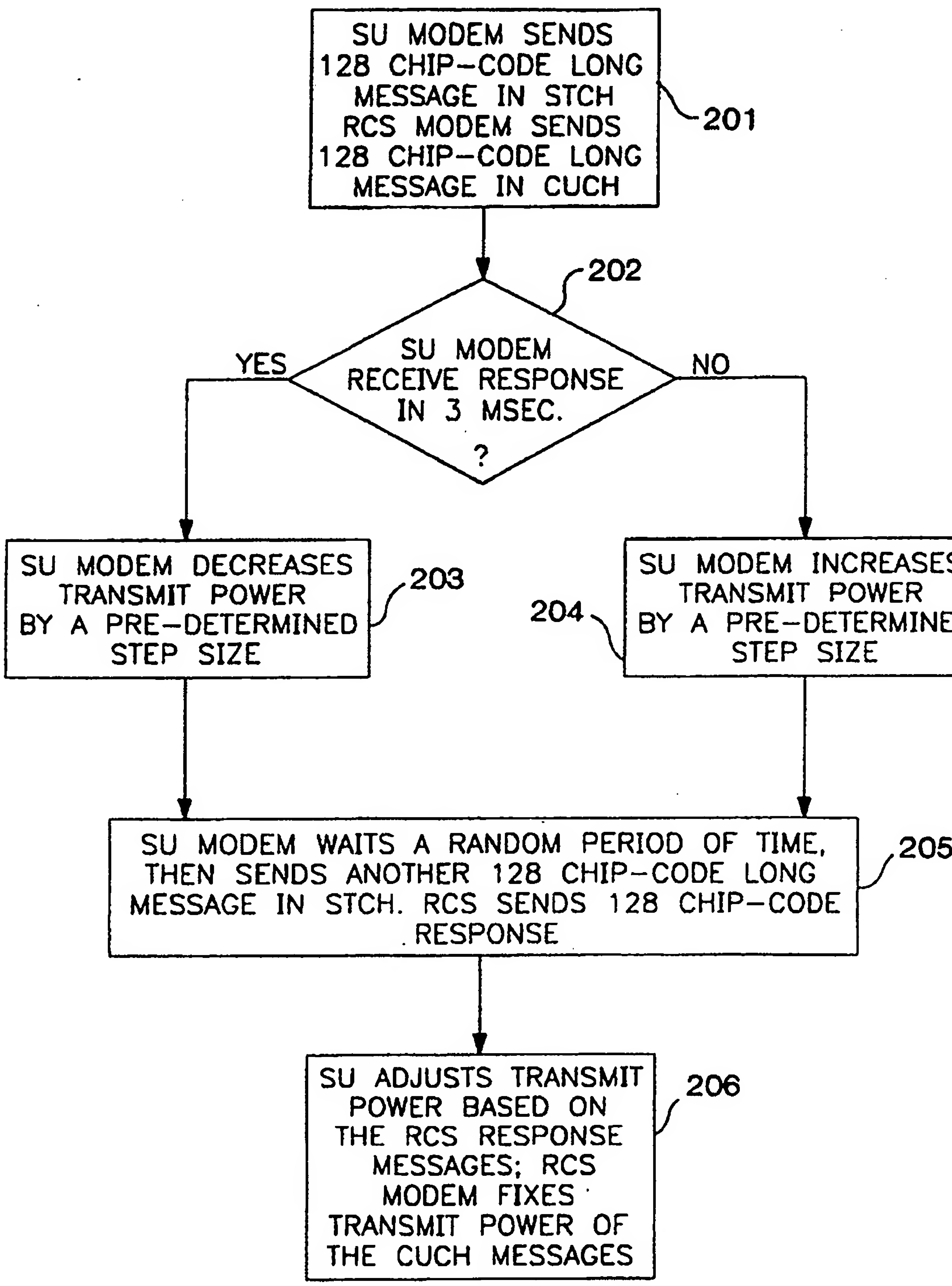
FIG. 1



SU MODEM SENDS 128 CHIP-CODE LONG MESSAGE IN STCH RCS MODEM SENDS 128 CHIP-CODE LONG MESSAGE IN CUCH
201
202
SU MODEM RECEIVE RESPONSE IN 3 MSEC. ?
YES
NO
SU MODEM DECREASES TRANSMIT POWER BY A PRE-DETERMINED STEP SIZE
203
204
SU MODEM INCREASES TRANSMIT POWER BY A PRE-DETERMINED STEP SIZE
SU MODEM WAITS A RANDOM PERIOD OF TIME, THEN SENDS ANOTHER 128 CHIP-CODE LONG MESSAGE IN STCH. RCS SENDS 128 CHIP-CODE RESPONSE
205
SU ADJUSTS TRANSMIT POWER BASED ON THE RCS RESPONSE MESSAGES; RCS MODEM FIXES TRANSMIT POWER OF THE CUCH MESSAGES
206

FIG. 2

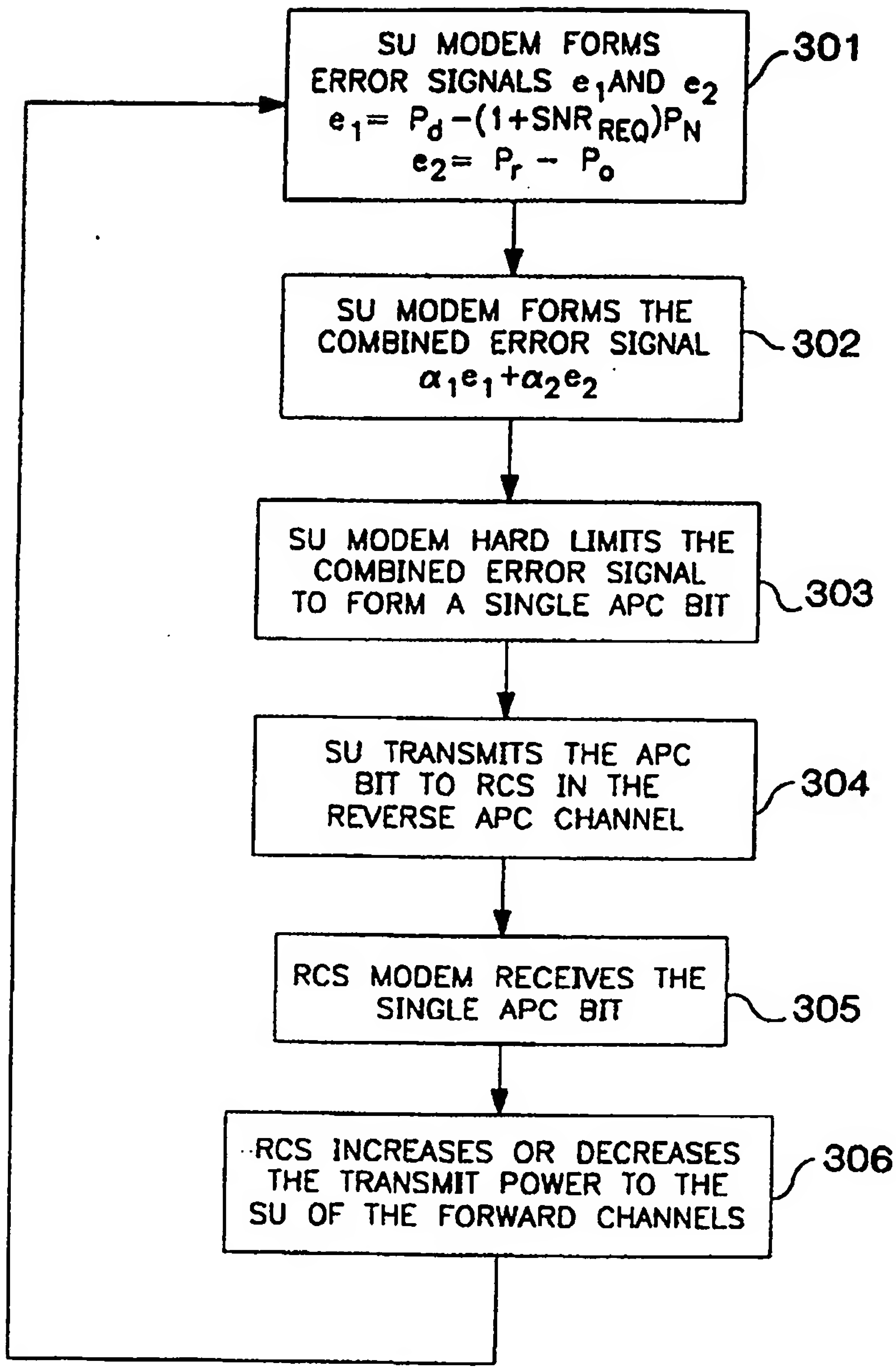

SU MODEM FORMS ERROR SIGNALS e_1 AND e_2
$e_1 = P_d - (1+SNR_{REQ})P_N$
$e_2 = P_r - P_o$
301
SU MODEM FORMS THE COMBINED ERROR SIGNAL
$\alpha_1 e_1 + \alpha_2 e_2$
302
SU MODEM HARD LIMITS THE COMBINED ERROR SIGNAL TO FORM A SINGLE APC BIT
303
SU TRANSMITS THE APC BIT TO RCS IN THE REVERSE APC CHANNEL
304
RCS MODEM RECEIVES THE SINGLE APC BIT
305
RCS INCREASES OR DECREASES THE TRANSMIT POWER TO THE SU OF THE FORWARD CHANNELS
306

FIG. 3

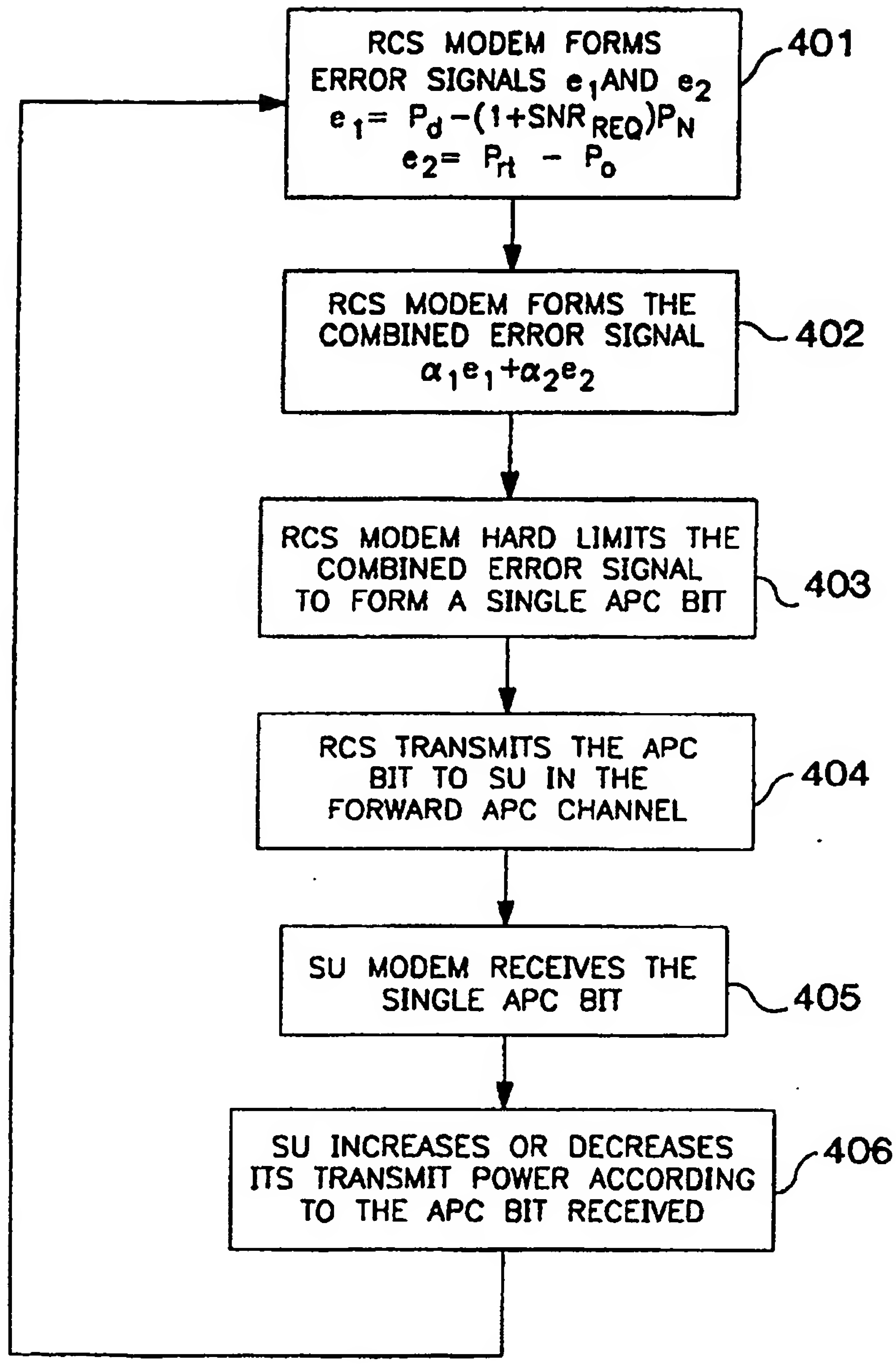
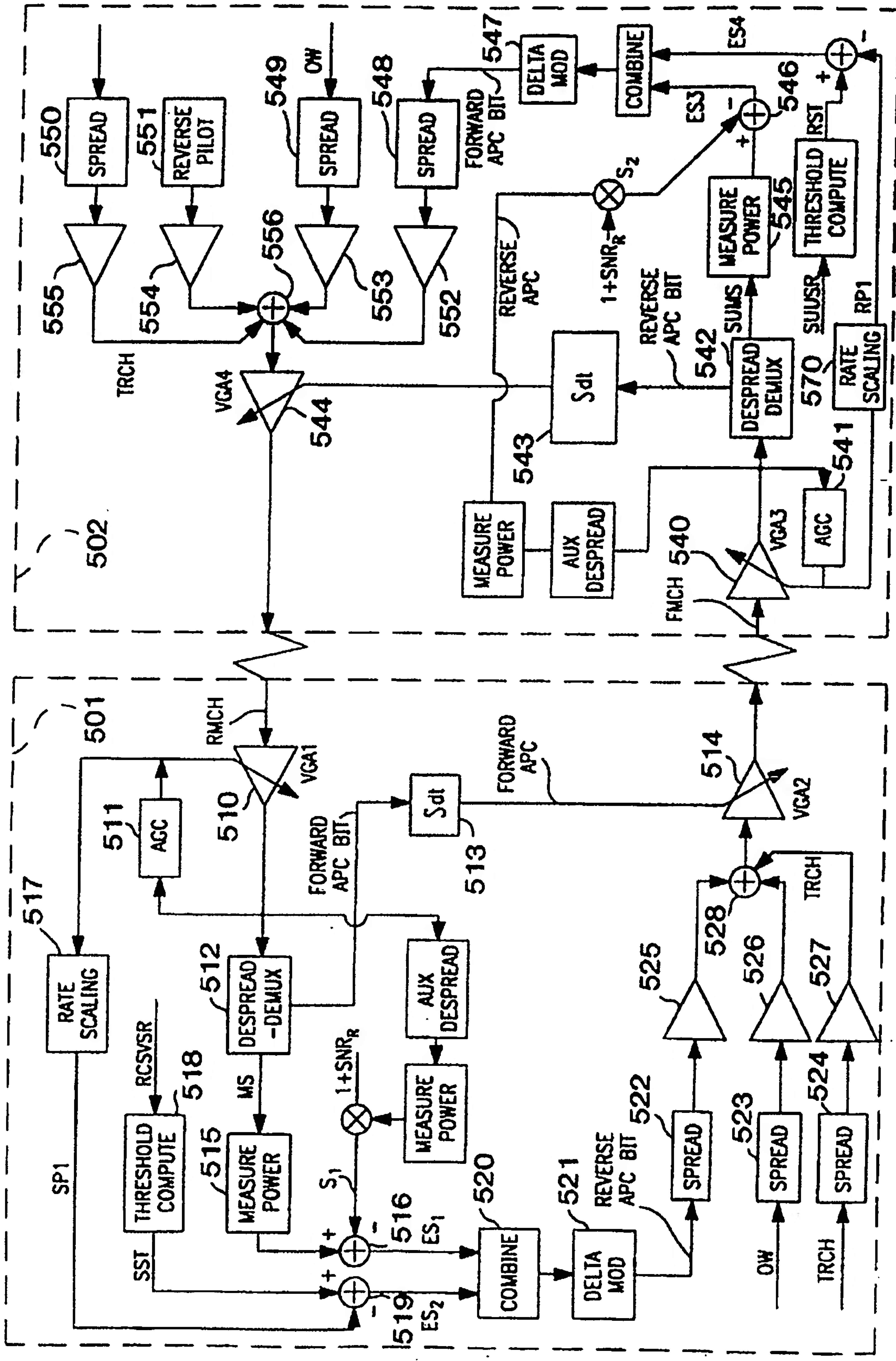

RCS MODEM FORMS ERROR SIGNALS e_1 AND e_2
$e_1 = P_d - (1+SNR_{REQ})P_N$
$e_2 = P_{rt} - P_o$
401
RCS MODEM FORMS THE COMBINED ERROR SIGNAL
$\alpha_1 e_1 + \alpha_2 e_2$
402
RCS MODEM HARD LIMITS THE COMBINED ERROR SIGNAL TO FORM A SINGLE APC BIT
403
RCS TRANSMITS THE APC BIT TO SU IN THE FORWARD APC CHANNEL
404
SU MODEM RECEIVES THE SINGLE APC BIT
405
SU INCREASES OR DECREASES ITS TRANSMIT POWER ACCORDING TO THE APC BIT RECEIVED
406

FIG. 4


SPREAD
REVERSE PILOT
OW
DELTA MOD
COMBINE
ES4
ES3
FORWARD APC BIT
REVERSE APC
1+SNR
MEASURE POWER
THRESHOLD COMPUTE
RST
SUMS
SUUSR
RP1
RATE SCALING
DESPREAD DEMUX
REVERSE APC BIT
TRCH
VGA4
VGA3
AGC
AUX DESPREAD
FMCH
RMCH
VGA1
VGA2
FORWARD APC
DESPREAD -DEMUX
RCSVSR
MS
SST
SP1
ES1
ES2
550
551
549
548
547
546
545
556
555
554
553
552
544
543
542
541
540
570
502
501
510
511
512
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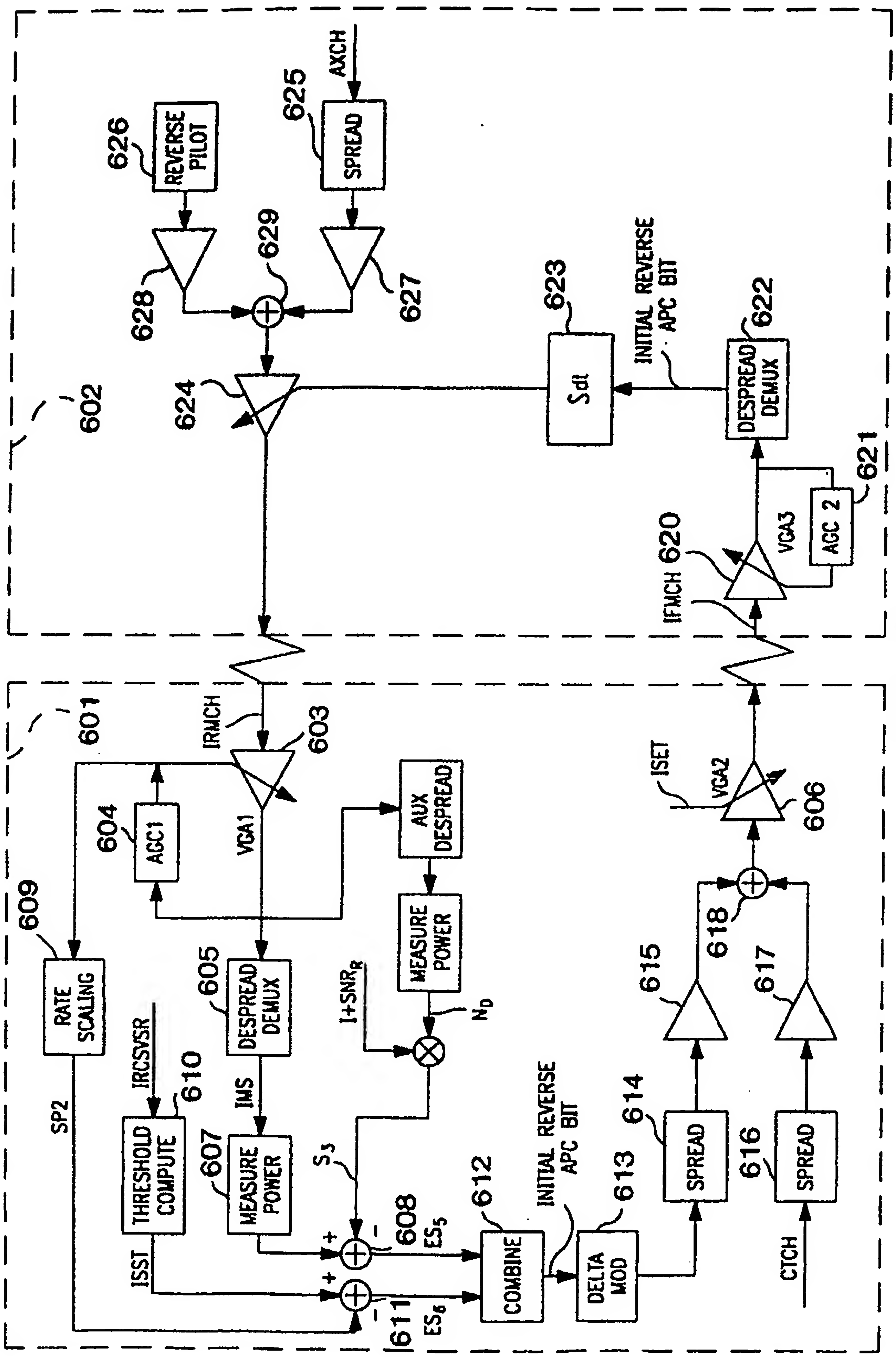
526
527
528

FIG. 5



AXCH
625
SPREAD
626
REVERSE PILOT
629
628
627
624
602
623
S_{dt}
INITIAL REVERSE APC BIT
622
DESPREAD DEMUX
621
AGC 2
VGA3
620
IFMCH
601
IRMCH
603
604
AGC1
VGA1
AUX DESPREAD
MEASURE POWER
N_D
$I+SNR_R$
609
RATE SCALING
SP2
605
DESPREAD DEMUX
IMS
IRCSVSR
610
THRESHOLD COMPUTE
ISST
607
MEASURE POWER
S_3
608
ES_5
611
ES_6
612
COMBINE
INITIAL REVERSE APC BIT
613
DELTA MOD
614
SPREAD
615
618
616
SPREAD
617
CTCH
ISET
VGA2
606

FIG. 6

PCT

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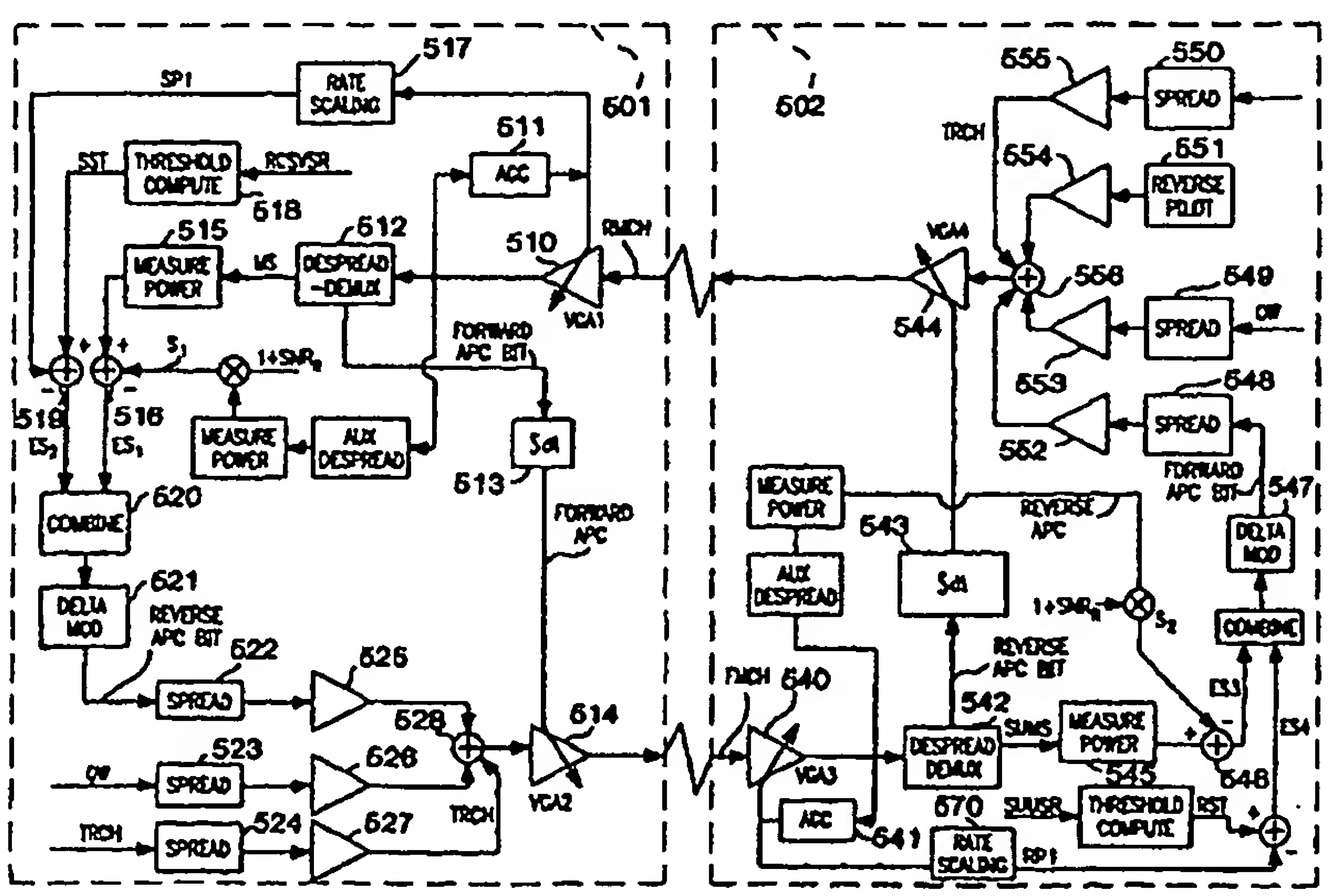
(57) Abstract



An automatic power control (APC) system for a spread-spectrum communications system includes an automatic forward power control (AFPC) system, and an automatic reverse power control (ARPC) system. In the AFPC, each subscriber unit (SU) measures a forward signal-to-noise ratio of a respective forward channel information signal to generate a respective forward channel error signal which includes a measure of the uncorrelated noise in the channel and a measure of the error between the respective forward signal-to-noise ration and a pre determined signal-to-noise value. A control signal generated from the respective forward channel error signal is transmitted as part of a respective reverse channel information signal. A base unit includes AFPC receivers which receive respective reverse channel information signals and extract the forward channel error signals therefrom to adjust the power levels of the respective forward spread-spectrum signals. In the ARPC system, each base measures a reverse signal-to-noise ratio of each of the respective reverse channel information signals and generates a respective reverse channel error signal which includes a measure of the uncorrelated noise in the channel and a measure of the error between the respective reverse signal-to-noise ratio and a pre determined signal-to-noise value. The base unit transmits a control signal generated from the respective reverse channel error signal as a part of a respective forward channel information signal. Each SU includes an ARPC receiver which receives the forward channel information signal and extracts the respective reverse error signal to adjust the reverse transmit power level of the respective reverse spread-spectrum signal.

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/11060

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04B7/005 H04B7/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 245 629 A (HALL SCOTT M) 14 September 1993 see column 2, line 6 - line 16 see claims 9-12,17 ---	1,2,4-6, 9,10
X	US 5 265 119 A (GILHOUSEN KLEIN S ET AL) 23 November 1993 see column 9, line 17 - line 26 see column 13, line 34 - column 17, line 44; figures 3,4 see column 18, line 19 - column 19, line 53 ---	1,2,4-6, 9,10
A	EP 0 656 716 A (CSELT CENTRO STUDI LAB TELECOM) 7 June 1995 see page 2, line 54 - page 3, line 19; claim 1 -----	1,2,4-6, 9,10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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2

Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	BOSSEN, M

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 96/11060

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. claims 1-12: automatic power control in a CDMA communication system
2. claims 13,14: automatic maintenance power control

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

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1-12

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 96/11060

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(54) **CDMA WIRELESS CHANNEL ALLOCATION METHOD ENABLING HANDOFF CHANNEL RESERVATION**

ABSTRACT

The present invention relates to a CDMA wireless channel allocation method enabling a handoff reservation.

The prior art has a problem in that, in the case of variable link capacity, it is difficult to reserve a dedicated handoff channel. Therefore, the present invention subtracts the currently received interference from two total interference margins set by the BS, classifies two signal intensity margins, and allocates a wireless channel accordingly so that a dedicated handoff channel can be reserved.

SPECIFICATION

[TITLE OF THE INVENTION]

CDMA WIRELESS CHANNEL ALLOCATION METHOD ENABLING HANDOFF CHANNEL RESERVATION

[BRIEF DESCRIPTION OF THE DRAWINGS]

FIG. 1 shows the construction of a BS receiver for wireless channel allocation according to the present invention; and

FIG. 2 is a flowchart showing CDMA wireless channel

allocation according to the present invention.

* Reference numerals of several elements in the drawings *

101: RF (Radio Frequency) processor

102: received signal intensity measurer

103: correlator (or match filter)

104: channel processor

105: BS (Base Station) controller

[DETAILED DESCRIPTION OF THE INVENTION]

The present invention relates to a CDMA wireless channel allocation method enabling a handoff channel reservation so that terminal users in a CDMA (Code Division Multiple Access) cellular system are provided with improved quality (grade) of services.

In general, handoff (i.e. communication channel switching) refers to the switching of wireless links so that the communication path between BSs remains connected.

Particularly, during handoff, the BS selects a channel having the best field strength received by terminals so that the communication path remains intact. However, if a cellular system fails to hand off properly, the call tends to drop during communication.

Such a call drop has a worse influence on users than a failed call seed (call blocking).

The influence is evaluated in terms of GOS (Grade of

Service) according to DECT (Digital European Cordless Telephone) standards. Therefore, it is customary to reserve a dedicated handoff channel to improve the GOS. However, the ever-changing CDMA link capacity makes it difficult to efficiently reserve a dedicated handoff channel.

In the case of a CDMA system based on SS (Spread Spectrum), the wireless link capacity varies depending on the interference included in the wireless link, even if the bandwidth is the same, unlike FDMA (Frequency Division Multiple Access) or TDMA (Time Division Multiple Access) systems.

In addition, the capacity of uplinks (wireless links leading from terminals to BSs) is smaller than that of downlinks (wireless links leading from BSs to terminals). This means that the wireless link capacity of CDMA systems depends on the capacity of the uplinks.

For example, assuming that the GOS is expressed in terms of Eb/No, the value of which is 7dB, the CDMA link capacity N is given as follows according to IS-95 Standards relating that the bandwidth is 1.2288MHz and that the information transmission rate of a user is 9.6Kbps.

However, when it comes to the actual link capacity of CDMA cellular systems, the voice activity, background noise, and sectorization effect must also be considered.

In particular, the interference received by BSs is

received not only by those using their own cells, but also those using external cells. The interference in external cells varies depending on external environments, such as radio wave characteristics, handoff region size, etc.

In summary, the CDMA link capacity depends on external environments. Therefore, it is uneconomical to allocate CDMA wireless channels based on fixed link capacity, because available channels of wireless links are not fully availed of. Instead, it is efficient to allocate wireless link channels based on the received interference.

However, no conventional methods properly consider a dedicated handoff channel and still fail to improve the GOS. It is even more difficult to reserve a dedicated handoff channel in the case of varying capacity.

Accordingly, the present invention has been made to solve the above-mentioned problems occurring in the prior art, and an object of the present invention is to provide a CDMA wireless channel allocation method enabling a handoff channel reservation so that, as a scheme for allocating a wireless link channel between a base station and a mobile station (or personal portable terminal), a dedicated handoff channel is reserved to allocate channels and provide users with improved quality (grade) of services.

In order to accomplish this object, the present invention provides a method for allocating a wireless

channel according to the intensity of signals received by a base station in a CDMA cellular system so that a handoff channel can be reserved, the method including a first step of subtracting currently received signal intensity from a first total interference margin (TIM) and a second total interference margin (TIM-1) set by the base station to calculate a current signal intensity margin (CIM) and a handoff signal intensity margin (HIM), respectively; a second step of checking if signal intensity necessary to allocate a channel for a call exceeds the current signal intensity margin (CIM) when the channel has been requested after the first step; a third step of checking if the requested call is handoff when it has been confirmed in the second step that the signal intensity necessary to allocate the channel exceeds the current signal intensity margin (CIM); and a fourth step of allocating new wireless channels until the signal intensity necessary to allocate the channel does not exceed the handoff signal intensity margin (HIM) when it has been confirmed in the third step that the requested call is handoff.

Hereinafter, the present invention will be described in detail with reference to the accompanying drawings.

FIG. 1 shows the construction of a BS receiver necessary to efficiently allocate wireless channels. The BS receiver includes an RF processor 101 for receiving RF

signals modulated on a wireless basis, a number of correlators (or match filters) 103 for detecting digital signals from the modulated RF signals, a number of channel processors 104 for decoding the digital signals, which have been demodulated by the correlators (or match filters) 103, into original digital signals channel by channel, and a BS controller 105 for managing and controlling these components.

The BS receiver further includes a received signal intensity measurer 102 for measuring the intensity of the modulated signals received by the RF processor 101, before they are transferred to the correlators 103, and transmitting the measured intensity to the BS controller 105.

The intensity of received signals is substantially equal to the interference received by the correlators 103.

FIG. 2 is a flowchart showing steps for reserving a dedicated handoff channel by the BS controller 105 shown in FIG. 1 and efficiently allocating CDMA wireless channels. The steps will now be described with reference to FIG. 2.

In step 1 (S1), the BS controller 105 sets two total interference margins TIM and TIM-1 allocated by the network.

The difference between the TIM and TIM-1 depends on the product of the number of handoff channels to be

reserved and the increase in received signal intensity resulting from the allocation of a channel.

In step 2 (S2), the received signal intensity (i.e. received interference) measured by the received signal intensity measurer 102 is read at a cycle smaller than the channel request cycle. Particularly, it is enough to read the received signal intensity at a cycle corresponding to 1/10 of the channel request cycle.

In step 3(S3), the currently read interference is subtracted from the two total interference margins TIM and TIM-1 obtained in step 2, respectively, to calculate two signal intensity margins CIM (current IM) and HIM (Handoff IM).

If a new call or handoff requests in step 4 (S4) that a new wireless channel be allocated, the signal intensity (power) necessary to allocate a channel for the call is calculated in step 5 (S5).

In case of a voice service provided in the worst condition, the signal intensity is fixed. In step 6 (S6), it is checked if the signal intensity necessary for the wireless channel allocation exceeds the CIM. If it is confirmed as a result of the check that the CIM is not exceeded, a new wireless channel is allocated in step 7 (S7). If it is confirmed in the check (S6) that the CIM is exceeded, it is determined if the requested call is handoff

in step 8 (S8). If it is confirmed that the requested call is handoff, it is checked in step 9 (S9) if the signal intensity necessary for channel allocation calculated in step 5 (S5) exceeds the HIM.

If it is confirmed in the check (S9) that the HIM is not exceeded, a new wireless channel is allocated as in step 7 (S7). If the HIM is exceeded, the request for the wireless channel allocation is rejected in step 10 (S10). This will be described in more detail with reference to FIG. 2.

The BS controller 105 sets total interference margins allocated by the network. For example, the first total interference margin TIM is set to be 90, and the second total interference margin TIM-1 is set to be 100 (S1).

The unit of each number is omitted for convenience of description. The currently received interference resulting from external environments is read by the received signal intensity measurer (S2).

The two signal intensity margins CIM and HIM are calculated as follows (S3). Assuming that the currently received and read interference (i.e. received signal intensity) is 60, the current intensity margin (hereinafter, referred to as CIM) is obtained by subtracting the currently read interference 60 from TIM=90, and becomes 30. Similarly, the handoff intensity margin

(hereinafter, referred to as HIM) is obtained by subtracting the currently read interference 60 from TIM-1=100, and becomes 40.

Alternatively, if the currently received and read interference is 80, the calculation result is CIM=10, HIM=20.

To give another example, if the currently received and read interference is 90, the calculation result is CIM=0, HIM=10. If a new call or handoff requests that a new wireless channel be allocated (S4), signal intensity (or power consumption) necessary for the wireless channel allocation is calculated (S5).

It is assumed that the signal intensity necessary to allocate a channel is 1 (this can be varied at any moment).

Based on this assumption, the signal intensity necessary to allocate ten channels (i.e. signal intensity necessary to secure ten channels) is 10. Besides this assumption, if the currently received signal intensity is 60 and if a new channel is requested, as mentioned above, the signal intensity necessary to allocate a new channel (i.e. 1) does not exceed CIM=30, which has been calculated in S3. This means that a new wireless channel can be allocated.

However, if the currently received signal intensity is 90 and if a channel is requested, the signal intensity

necessary to allocate a new channel (i.e. 1) exceeds CIM=0, which has been calculated in S3 (according to S6). In this case, dedicated handoff channels, which have been reserved, are solely used.

Particularly, if the signal intensity necessary to allocate a new channel exceeds the CIM and if the requested call is not handoff (S8), a normal call is rejected. However, if the requested call is handoff (S8), a new wireless channel is allocated because the signal intensity (i.e. 1) necessary for channel allocation calculated in S5 does not exceed HIM=10 calculated in S3.

If the signal intensity 1 exceeds the HIM, the wireless channel allocation is rejected because all dedicated handoff channels have been used (S10).

The above examples confirm that, according to the present invention, dedicated handoff channels can be reserved in the case of varying link capacity.

As mentioned above, the present invention can maximize the efficiency of CDMA wireless resources by classifying the signal intensity margins by the BS receiver of a CDMA system and allocating wireless channels accordingly.

In addition, reservation of dedicated handoff channels improves service quality.

Furthermore, easy implementation makes it possible to expect an economic CDMA system.

(57) WHAT IS CLAIMED IS:

1. A method for allocating a wireless channel according to intensity of signals received by a base station in a CDMA cellular system so that a handoff channel can be reserved, the method comprising:

a first step of subtracting currently received signal intensity from a first total interference margin (TIM) and a second total interference margin (TIM-1) set by the base station to calculate a current signal intensity margin (CIM) and a handoff signal intensity margin (HIM), respectively;

a second step of checking if signal intensity necessary to allocate a channel for a call exceeds the current signal intensity margin (CIM) when the channel has been requested after the first step;

a third step of checking if the requested call is handoff when it has been confirmed in the second step that the signal intensity necessary to allocate the channel exceeds the current signal intensity margin (CIM); and

a fourth step of allocating new wireless channels until the signal intensity necessary to allocate the channel does not exceed the handoff signal intensity margin (HIM) when it has been confirmed in the third step that the requested call is handoff.

DRAWINGS

FIG. 1

101: RF PROCESSOR

102: RECEIVED SIGNAL INTENSITY MEASURER

103: CORRELATOR OR MATCH FILTER

104: CHANNEL PROCESSOR

105: BS CONTROLLER

FIG. 2

S1: SET TOTAL INTERFERENCE MARGINS (TIM, TIM-1)

S2: READ RECEIVED INTERFERENCE

S3: CALCULATE SIGNAL INTENSITY MARGINS (CIM, HIM)

S4: CHANNEL REQUEST EXISTS?

예: YES

아니오: NO

S5: CALCULATE CHANNEL ALLOCATION POWER CONSUMPTION

S6: CIM EXCEEDED?

S7: ALLOCATE NEW WIRELESS CHANNEL

S8: HANDOFF?

S9: HIM EXCEEDED?

S10: REJECT WIRELESS CHANNEL ALLOCATION